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EFFECT OF FLOW EQUALIZATION ON WATER POLLUTION CONTROL PLANT PERFORMANCE

by

Dearborn Environmental Consulting Services

for

Canada Mortgage and Housing Corporation

Report SCAT-4
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ABSTRACT

The feasibility of using flow equalization to reduce the overall cost of municipal wastewater treatment was the subject of this two-phase study. In the initial phase, covered in this report, the effect of flow equalization at the Stouffville Water Pollution Control Plant was evaluated to define those factors which influence the general applicability of the process, and to serve as a guide for defining the detailed objectives of the Phase II studies.

At the Stouffville plant two identical parallel treatment systems were operated, one under equalized flow conditions and the other under non-equalized flow conditions to serve as a comparative control. The performance of the plant was monitored under dry weather flow conditions during the fall of 1976, and under wet weather flow conditions (i.e., substantially higher total flow) during the spring of 1977. In the fall both systems were operated at similar average daily hydraulic loadings, while in the spring, the average hydraulic loading on the equalized system was increased by approximately 15 percent relative to the non-equalized system.

During the fall sampling period, the equalized system produced a consistently better secondary effluent in the terms of total biochemical oxygen demand and suspended solids. Phosphorus removal was unaffected by the operating mode, and sludge production rates were similar. During the spring sampling period, despite the higher hydraulic loading on the equalized system, there was no significant difference in effluent quality between the two systems. Operational control of the biological solids concentration was noticeably simplified in the equalized system.

RÉSUMÉ

L'étude qui comprenait deux étapes a porté sur la possibilité de régulariser le débit pour réduire le coût global de l'épuration des eaux urbaines. La première étape, qui fait l'objet du présent rapport et qui a été réalisée à l'usine d'épuration des eaux de Stouffville, a permis de définir les facteurs qui interviennent dans le procédé de régularisation du débit et les objectifs détaillés de la seconde étape.

Deux installations identiques ont été exploitées en parallèle, l'une à débit régularisé, l'autre comme témoin. Les expériences se sont déroulées à l'automne de 1976, c'est-à-dire par temps sec, et au printemps de 1977, par temps humide (le débit était notablement plus élevé). À l'automne, la charge hydraulique quotidienne des deux installations était en moyenne similaire, tandis qu'au printemps celle de l'installation régularisée était supérieure de 15% à celle du témoin.

À l'automne, la DBO et la teneur en MES de l'effluent du traitement secondaire de l'installation régularisée étaient moindres que dans l'effluent témoin, tandis que le degré de déphosphatation et la production de boue étaient semblables. Au printemps, les deux installations ont produit un effluent de qualité similaire, malgré une charge hydraulique supérieure dans celle à débit régularisé. Dans cette dernière, l'élimination des matières biologiques a été notablement simplifiée.

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CONCLUSIONS AND RECOMMENDATIONS

CONCLUSIONS

As a result of this study, a number of conclusions specific to flow equalization at the Stouffville Water Pollution Control Plant as well as further general conclusions regarding factors affecting the overall feasibility of flow equalization can be made.

From the results obtained at Stouffville, based on 24-hour composite sampling, the following specific conclusions can be drawn:

1) There was no quantitative effect on average raw sewage quality resulting from flow equalization. However, limited discrete sampling data indicated that some concentration equalization occurred in the equalization tank.
2) There was no significant difference between primary effluent qualities under equalized and non-equalized flow conditions at equivalent daily hydraulic loadings.
3) Under equivalent daily loading, the equalized system produced a consistently better quality secondary effluent. The average total BOD of the equalized system's effluent was 13 mg/L (ranging from 8 to 27 mg/L) as compared to 28 mg/L (ranging from 15 to 42 mg/L) for the non-equalized system's effluent. Similarly, the average suspended solids' concentrations were 16 mg/L (ranging from 8 to 21 mg/L) and 28 mg/L (ranging from 16 to 49 mg/L) for the equalized and non-equalized systems' effluents, respectively.
4) Average daily hydraulic loading to the equalized system could be increased by at least 15 percent without any deterioration in secondary effluent quality relative to the parallel non-equalized system at a lower loading.
5) At the hydraulic and organic loadings experienced during the study, flow equalization did not affect the removal of soluble BOD. Adequate capacity was available to provide stabilization of the organic matter.
6) Under equalized flow conditions, there was no correlation between secondary clarifier hydraulic loading and secondary effluent suspended solids content over the upflow range of 20 to 44 $m^3/m^2 \cdot d$. The critical loading of the clarifier was not exceeded during this investigation.

Effect of Flow Equalization on Water Pollution Control Plant Performance

7) Phosphorus removal efficiency was not affected by the operating mode.

8) During by-passes of the treatment system, the flow equalization tank functioned as a primary clarifier, resulting in an average removal of 7.2 kg of suspended solids and 1.2 kg of BOD per 1000 m^3 of by-passed sewage. This represents 50 percent suspended solids' and 10 percent BOD removal.

9) There was no significant difference in solids' production per 1000 m^3 treated as a result of flow equalization.

10) Flow equalization at Stouffville improves operational control of the treatment system. Specifically, mixed liquor suspended solids concentrations could be more readily maintained under equalized flow conditions facilitating plant control based on solids retention time.

11) Net increase in power costs attributable to flow equalization under the study conditions at the Stouffville Water Pollution Control Plant were approximately $3.68 per day, which represents less than two percent of the total operating cost.

12) Capital cost of the equalization tank at Stouffville was $88 820 in 1972 or approximately 10 percent of the overall cost of the treatment plant. This compares favourably with the additional 15 percent of sewage volume processed under equalized flow conditions. Moreover, the 15 percent increase in plant capacity demonstrated during this study does not necessarily represent the maximum load that could be treated successfully by the Stouffville plant under equalized flow conditions.

13) The facility at Stouffville has limitations for further evaluation of flow equalization due to the limited flexibility of the design.

During the investigation, the following general conclusions regarding flow equalization as a process alternative were formulated:

i) Flow equalization is one of many alternatives capable of improving plant performance and should be evaluated on its own merits under the specific set of circumstances.

ii) The major benefit of flow equalization appears to be in reducing the instantaneous peak loading on the clarifiers throughout the plant. If the clarifier is loaded beyond its capacity under instantaneous peak hydraulic loading conditions and flow equalization can reduce this instantaneous loading below the critical level, it will be very beneficial to the process performance.

This peak hydraulic loading may be a result of the diurnal flow pattern and/or the pumping arrangements in the sewer system and at the plant influent works.

iii) More complex process sequences or processes efficient over a narrow range of hydraulic or organic loadings will benefit most by flow equalization.

iv) Equalization basins can be designed as primary clarifiers and thus reduce the loading on the receiving water body during by-passes of the treatment system.

v) Operational costs attributable to flow equalization are site-specific and primarily controlled by the design of the pumping system. In most cases, the increased operating cost resulting from flow equalization will be relatively insignificant.

vi) The capital cost implications of flow equalization are site-specific and depend on such factors as:

- whether the situation under study involves an expansion to an existing facility or a new installation;
- dry and wet weather flow variations, including instantaneous loadings, expected or experienced at the plant, and the effects on plant operation;
- the complexity of treatment processes involved;
- the rate of occurrence and impact of high flow by-passes, and the economic implications of alternate methods of handling these by-passes; and
- the possible capital savings involved in the design of treatment units under equalized flow conditions.

vii) The existing methodology for evaluating the implications and economic feasibility of flow equalization deals only with the diurnal flow variations experienced at the treatment plant without consideration of such other aspects as the effect of pumping arrangement on the sewage delivery pattern to the plant and the minimization or partial treatment of high flow by-passes.

RECOMMENDATIONS

Based on the conclusions resulting from these investigations, further studies are recommended as follows:

1) The effect of instantaneous loading on the performance of primary and secondary clarifiers should be investigated to evaluate the benefits in this regard that could be

realized by flow equalization. Data relating to instantaneous hydraulic loading and clarifier performance are not at present available.

2) Controlled pilot-scale studies should be conducted to document the effect of flow equalization on complex and hydraulically sensitive processes.

3) The applicability of flow equalization in control of treatment plant by-passes and sewer overflows resulting from short-term, high-intensity precipitation should be assessed. Such an assessment should include an investigation of the use of flow equalization as a means of increasing the volume of sewage treated in existing facilities (in order to reduce the occurrence of sewer system overflows and plant by-passes), and of its effectiveness in providing partial treatment of sewage flows beyond plant capacity.

4) A new methodology for assessing the implications and economic feasibility of flow equalization should be developed. Such factors as flow patterns, pumping arrangements, plant by-passes, sewer overflows and treatment process sequences should be considered in relation to the site-specific applicability of the process.

1 INTRODUCTION

For decades many municipalities in Canada have been served by secondary water pollution control plants. At the time of commissioning these treatment plants, they were capable of meeting the appropriate discharge requirements. The growth of municipalities in conjunction with increasingly stringent effluent quality criteria has led, however, to a continuous program of treatment plant expansion and improvement in process efficiency. Treatment and disposal of municipal wastewaters now represents a significant fraction of municipal budgets. The Regional Municipality of York spent approximately 7.5 percent of its total operating budget in 1977 on sewage treatment.

Wastewater treatment processes operate optimally at their design conditions, but because of activities in the community that result in diurnal variation in wastewater flows, these conditions occur for only a very small percentage of the time. The objective of flow equalization is to reduce the diurnal flow variation and thus achieve a more constant sewage flow rate through the treatment units. A flow equalization tank can also reduce the occurrence of high-flow by-passes resulting from short-term, high-intensity precipitation and provide primary treatment to sewage that cannot be accommodated in the plant. Considering these factors, flow equalization can result in an overall reduction of contaminant load to the receiving stream.

Flow equalization has been successfully practiced in Europe for a number of years. Several pilot and full-scale studies have also been conducted in the United States (1-5). Although numerous benefits have been ascribed to equalization of municipal wastewater flows, few Canadian municipalities have added equalization facilities.

The Regional Municipality of York has six water pollution control plants equipped with flow equalization facilities:

- Whitchurch-Stouffville Water Pollution Control Plant,
- Richmond Hill Water Pollution Control Plant,
- Unionville Water Pollution Control Plant,
- Tuclor Land Water Pollution Control Plant,
- Kleinburg Water Pollution Control Plant, and
- West Don Water Pollution Control Plant, which is not at present operating.

The municipality was therefore retained by Canada Mortgage and Housing Corporation under the terms of the SCAT Program, to investigate the effect of flow

equalization on the performance and cost of wastewater treatment facilities. Dearborn Environmental Consulting Services were retained by the Region to conduct the study under the direction of W.R. Hodgson, Commissioner of Engineering for the Regional Municipality of York.

Phase I of the program involved two separate sampling periods. The wastewater treatment facility was monitored under low flow conditions during the fall of 1976, and under high flow conditions during the spring of 1977. The results of both sampling periods are being used to define factors that will affect the technical and economical feasibility of flow equalization and to determine the areas to be investigated during the second phase.

2 STUDY OBJECTIVES

The overall objective of the investigation is to evaluate the effect of flow equalization on treatment plant operation, effluent quality, plant capacity and wastewater treatment costs.

The main objectives of Phase I of the investigation (the subject of this report) were the following: to determine factors affecting the feasibility of flow equalization, indicate areas that need further investigation, and define Phase II of the program. The detailed objectives of Phase I of the program were as follows:

1) to assess the effect of storage on the quality of the raw sewage;
2) to evaluate the effect of flow equalization on primary clarifier efficiency;
3) to determine the relative efficiency of conventional activated sludge systems operated under equalized and non-equalized flow conditions at equivalent daily hydraulic loadings;
4) to determine if a significant increase in treatment plant capacity can be attained under equalized flow conditions without deterioration in effluent quality;
5) to define the effect of flow equalization on the chemical precipitation of phosphorus from municipal sewage;
6) to compare the sludge production rates of wastewater treatment systems operated under equalized and non-equalized flow conditions;
7) to evaluate the cost implications of applying flow equalization at the Stouffville Water Pollution Control Plant;
8) to determine limitations which are inherent to the Stouffville Water Pollution Control Plant as an experimental facility; and
9) to determine factors that affect the feasibility of flow equalization and which therefore should be included in the assessment of equalization as a process alternative.

3 DESCRIPTION OF TREATMENT FACILITIES AND PLANT MODIFICATIONS

3.1 Treatment Plant Facilities

The Stouffville Water Pollution Control Plant, located on the south-east outskirts of the town, is operated by the Regional Municipality of York. The effluent from the plant is discharged into Dufferin Creek and subsequently flows into Lake Ontario. The plant is a conventional activated sludge treatment system designed to treat a flow of 2200 m^3/d.

The schematic view of the plant under normal operating conditions (Figure 1) shows two completely separate and identical treatment systems with common influent and effluent works, and a single anaerobic digester that services both systems. Flow equalization is provided in a side-line 633 m^3, 18-m diameter circular basin equipped with scum and sludge scraper mechanisms.

Under normal circumstances, the raw sewage flow to the two treatment plants is manually set by a magnetic flow controller on the discharge of the wet well lift pumps. Output from the pump in excess of the controlled flow to the plants is directed to the side-line equalization tank. The return flow from the equalization tank to the wet well is controlled by the level in the wet well through an automatic return valve. As the level in the wet well drops, the rate of return from the equalization tank increases proportionately. Flows in excess of the equalization tank capacity overflow from the basin directly to the chlorine contact chamber after separation of settleable solids.

The parallel treatment systems, denoted the North System and South System, are conventional in design. Basic design parameters for each system are:

Primary Clarifiers

Surface area	= 33 m^2 per clarifier
Design hydraulic loading	= 34 $m^3/m^2 \cdot d$

Aeration Tanks

Volume	= 296 m^3 per tank
Nominal retention time	= 6.5 h
Air supply	= 2 x 15 kW blowers

Secondary Clarifiers

Surface area	= 42 m^2 per clarifier
Design hydraulic loading	= 22 $m^3/m^2 \cdot d$

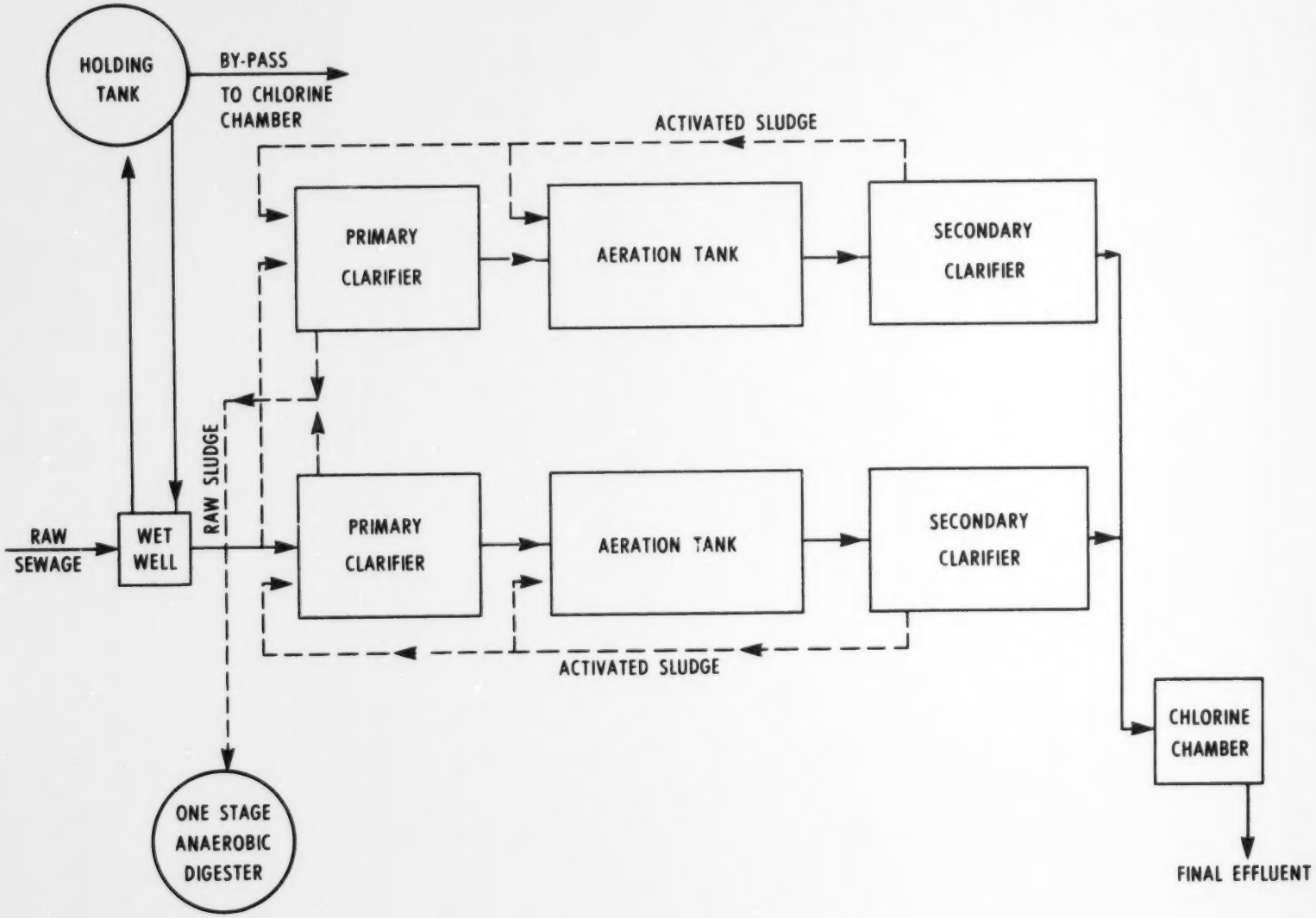

FIGURE 1 SCHEMATIC DIAGRAM OF STOUFFVILLE WATER POLLUTION CONTROL PLANT. NORMAL OPERATION

Ferrous chloride is added to each aeration tank at a dosage of approximately 11 mg Fe/L for phosphorus removal. The secondary effluents are combined prior to chlorination, polished on a sand filter bed and discharged to Dufferin Creek.

Sludges from the North and South Systems are not intermixed except within the single-stage anaerobic digester. Supernatant from the digester is returned to the raw sewage wet well and equally distributed between the two plants.

3.2 Treatment Plant Modifications

A schematic flowsheet of the Stouffville Water Pollution Control Plant as modified for the purposes of this study is shown in Figure 2. The basic modifications were the same for the fall 1976 and spring 1977 sampling periods, although the objectives and operating conditions were slightly different. During both monitoring periods, the North System was operated under equalized flow conditions. The South System was fed directly from the sewage wet well to serve as a control system under non-equalized flow conditions. The flow pattern was controlled upstream of the wet well by the design of the sewer system.

Approximately 60 percent of the raw sewage flows by gravity to the treatment plant. The remaining 40 percent is delivered from a single, level controlled pumping station located approximately 800 m from the plant. The inflow to the wet well therefore exhibits impulse peaks superimposed on the natural diurnal flow variations of the gravity section of the sewer system. Discussions with the consulting engineers for the Town of Whitchurch-Stouffville (Hisey and Barrington Limited) indicated that, although the system was designed as a sanitary sewer, there are innumerable weeping tile connections and a high degree of infiltration is experienced during wet weather periods.

The size of the influent wet well controls the rate at which raw sewage must be removed by the lift pump. The storage volume available between the on and off level controllers is limited. To provide some safety margin in the event of high wet weather flows, the minimum pumping rate of the raw sewage lift pump is about 3.0 m^3/min. The main lift pump operated approximately five minutes out of every 10 minutes during high flow periods.

With the existing pumping capabilities at Stouffville, the entire plant would operate in a similar mode if the equalization tank were not provided. Many small municipal plants do in fact operate in a similar fashion to the non-equalized South System. A list of several such plants in Ontario, covering a wide range of design, is provided in Table 1.

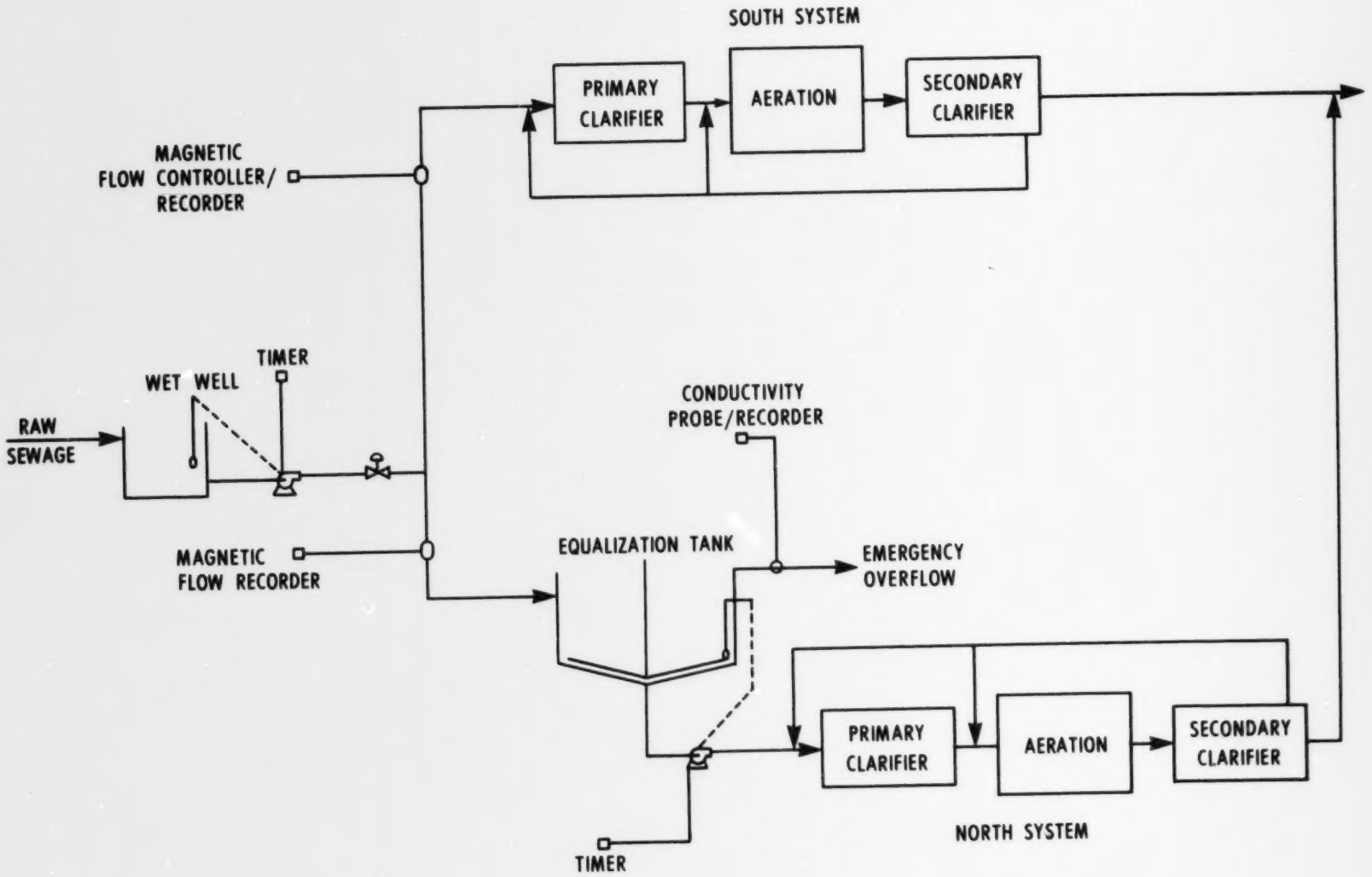

FIGURE 2 STOUFFVILLE WATER POLLUTION CONTROL PLANT. SCHEMATIC FLOWSHEET OF EQUALIZED AND NON-EQUALIZED SYSTEMS

TABLE 1 PARTIAL LISTING OF ONTARIO POLLUTION CONTROL PLANTS OPERATING IN ON-OFF SEWAGE FLOW MODE

Plant	Average Daily Flow (m^3/d)	Type of Plant
Alliston	2275	Activated Sludge
Amherstburg	3635	Biological Filter and Lagoon
Bradford	1820	Activated Sludge and Lagoon
Caledonia	450	Activated Sludge
Delhi	1820	Activated Sludge
Elora	910	Extended Aeration
Gravenhurst	1365	Activated Sludge
Kleinburg	225	Activated Sludge
Milton	3635	Tertiary (Lime)
Palmerston	1365	Activated Sludge
Port Elgin	1365	Extended Aeration
Simcoe	8182	Activated Sludge
Strathroy	2275	Lagoon
Sutton	450	Lagoon
Wallaceburg	1365	Activated Sludge

A single constant speed on-off level controlled lift pump was used to deliver raw sewage from the wet well to the equalization tank and the non-equalized South System. The flow to it was controlled and monitored by means of a manually-adjusted magnetic flow controller and recorder. Flow to the equalization tank was controlled by a manual throttling valve and monitored with a magnetic flow recorder. Total pump output was approximately 3.2 m^3/min. The lift pump output was equipped with a timer to monitor the actual pumping time.

Flow to the equalized North System was delivered from the in-line equalization tank by means of a manually-adjustable variable speed pump. A timer was provided to record daily pumping time to the equalized plant. Pump output was determined by means of a rectangular weir in the final effluent channel and by reference to the volume delivered to the equalization tank, the North System's pumping time and the level changes in the equalization tank.

A conductivity probe was installed on the overflow weir of the equalization tank and a recorder provided to monitor any occurrences of sewage by-pass from the tank. Samples of the overflow were collected to assess the quality of the by-pass stream.

A diesel pump activated by high-level wet well controllers was maintained in case of abnormally high flows or failure of the main lift pump. Output of this pump was directed to the equalization tank only.

Automatic samplers were installed to collect 24-hour composite samples of raw and equalized sewage, primary clarifier effluents and secondary clarifier effluents. Grab samples of aeration tank mixed liquors, waste activated sludges and raw primary clarifier sludges were collected manually. Sludge wastage rates were monitored to assess the effect of flow equalization on sludge production rates.

As a part of the fall sampling, discrete samplers were installed on the raw and equalized sewage and both secondary effluents for a 48-hour period. This sampling had only limited success due to extremely cold conditions, which created freezing problems.

During the fall 1976 sampling period, raw sewage flow to the influent works was divided equally between the non-equalized South System and the equalization tank of the North System. The average daily hydraulic loading of the two systems during this period was equal so as to assess the effect of flow equalization on effluent quality under similar loading conditions.

The spring 1977 program was designed to evaluate the feasibility of increasing plant capacity under equalized flow conditions. The average daily loading of the equalized North System was approximately 15 percent higher than that of the South System, relative to the average raw sewage influent flowrate. The results of the fall 1976 and spring 1977 monitoring programs are reviewed in Chapters 4 and 5 of this report, respectively.

4 RESULTS OF FALL 1976 MONITORING

The performance of the Stouffville plant under low flow conditions was monitored for a two-month period in November and December 1976. During this period, effluent quality under equalized and non-equalized flow conditions at equivalent average daily hydraulic loadings was the principal consideration.

4.1 Treatment Plant Hydraulic Loadings

The distribution of daily mean flows to the North and South Systems during the fall program is shown in Figure 3. The average and range of flow conditions are summarized in Table 2.

TABLE 2 RAW SEWAGE FLOWS TO EQUALIZED AND NON-EQUALIZED SYSTEMS. FALL SAMPLING

Plant	Average Daily Flow (m^3/d)	Average Pumping Time (h)	Average Instantaneous Loading* (m^3/min)
North System (Equalized)	1026	21.2	0.80
South System (Non-Equalized)	1016	10.5	1.66

* Average delivery rate to respective plants when pump is operating. Averaged over entire fall sampling period. Instantaneous loading varied on a daily basis depending on total raw sewage flow, pumping time and level in equalization tank.

There was no significant difference between average daily hydraulic loadings to the equalized and non-equalized systems during the two-month fall sampling period. However, some variation occurred on a daily basis between flows to the two systems because the flow division between the North and South Systems was manually controlled by throttling of the lift pump output. The maximum difference between loads to the two systems during the sampling period was 273 m^3/d, equivalent to a difference from the mean of $\pm$ 25 percent. These discrepancies were corrected as quickly as possible.

On only one occasion during the fall monitoring period was overflow from the equalization tank noted. The overflow was caused by plugging of the equalized plant feed pump by foreign material in the equalization tank. The stand-by diesel pump was not required during the sampling period.

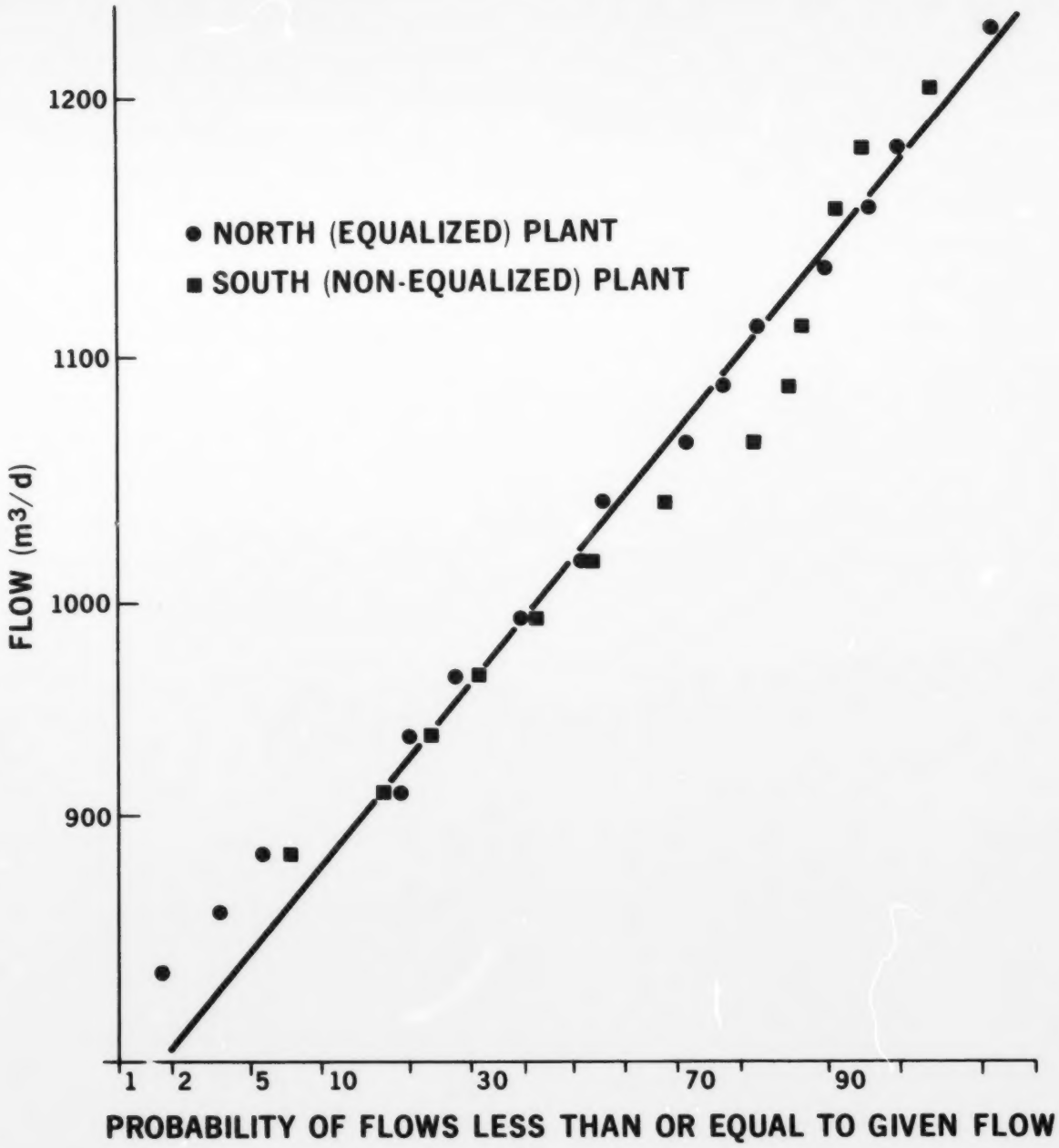

FIGURE 3 DAILY RAW SEWAGE FLOWS. FALL SAMPLING

Although the average daily hydraulic loadings of both systems were equal and within the design limits, the instantaneous loading of the non-equalized South System was high. At 1.59 m^3/min, the instantaneous surface loading of the south secondary clarifier was in excess of 54.0 $m^3/d \cdot m^2$.

The diurnal flow variations to the two systems were approximated from the plant flow records and pumping times for a representative one-week period from November 24 to December 1, 1976. Flow distribution data for the North and South Systems, based on the average of the hourly data from this seven-day period are illustrated in Figures 4 and 5, respectively. The flow data for the non-equalized South System exhibits a typical diurnal variation. The ratio of maximum hourly flow to minimum hourly flow for this period was approximately 2.3. In the equalized North System, however, the ratio of maximum to minimum hourly flow was reduced to 1.6 by the equalization tank.

Due to the relatively low flows to the treatment plant during this period, the North System did not operate under completely equalized conditions, as evident from the reduced flow during the early morning hours from approximately 2:00 A.M. and 8:00 A.M. Sufficient flow could not be stored during the high flow hours to maintain constant loading during the low flow periods. However, the results of the sampling program were not significantly affected by the low flows, as sampling was flow-proportional.

Table 3, based on the hydraulic analyses, summarizes the secondary clarifier loadings for the fall 1976 sampling period.

TABLE 3 SECONDARY CLARIFIER LOADINGS. FALL SAMPLING

	Secondary Clarifier Loading ($m^3/d \cdot m^2$)	
	Non-equalized System	Equalized System
Average Daily Flow	24.5	24.5
Instantaneous Peak Flow	55.8	29.4
Maximum Daily Flow	29.4	29.4
Maximum Hourly Flow (7-day period)	44.6	29.4

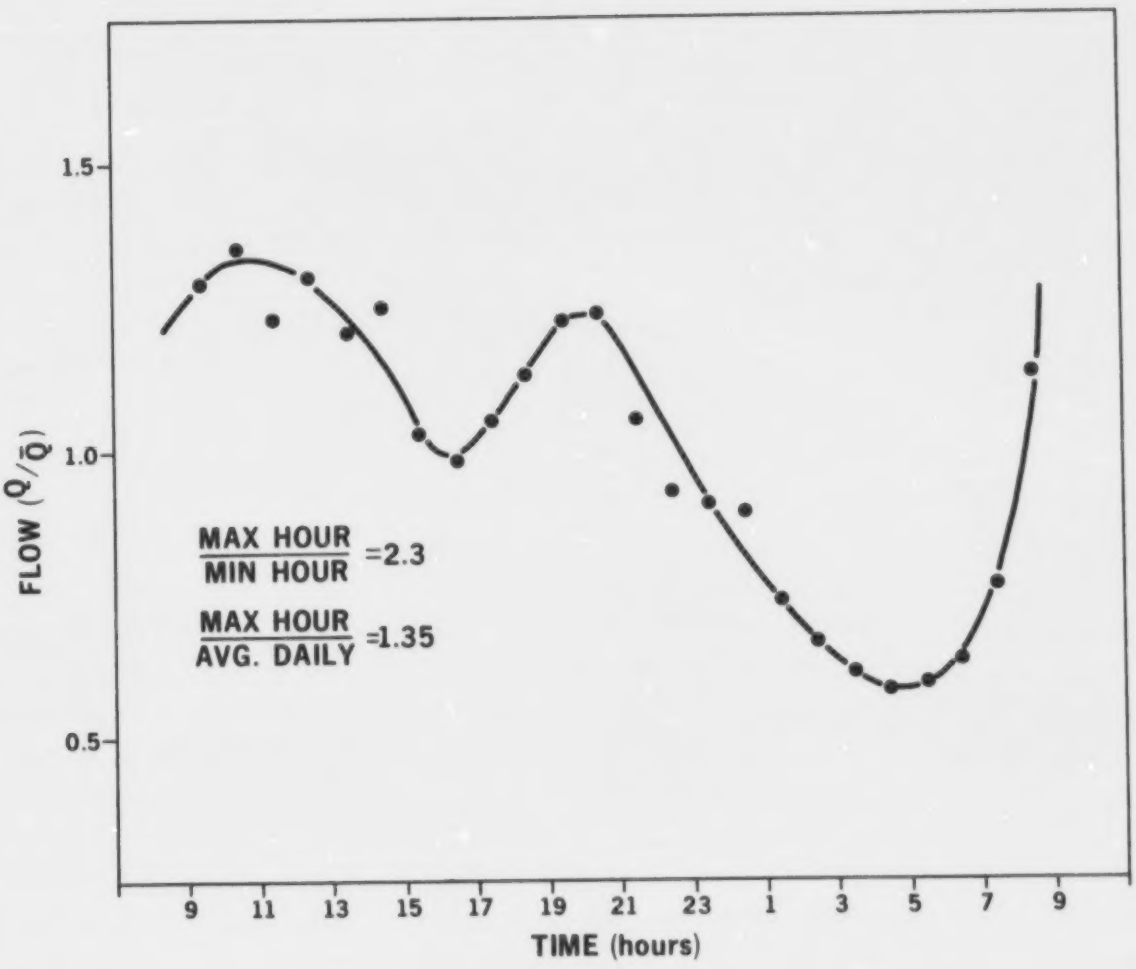

FIGURE 4 WEEKLY AVERAGE HOURLY FLOW DISTRIBUTION, NOVEMBER 24 TO DECEMBER 1, 1976. EQUALIZED SYSTEM

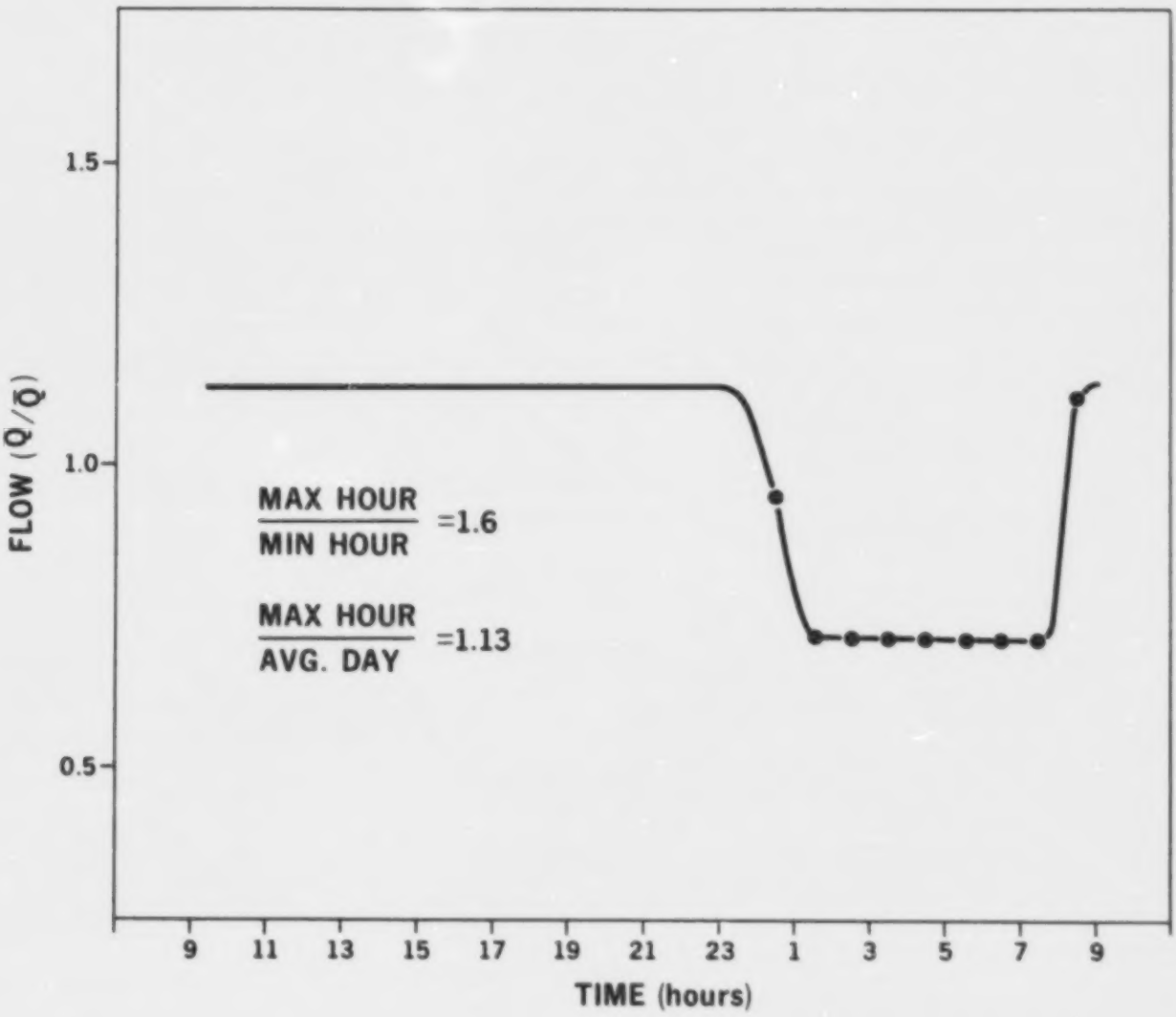

FIGURE 5 WEEKLY AVERAGE HOURLY FLOW DISTRIBUTION, NOVEMBER 24 TO DECEMBER 1, 1976. NON-EQUALIZED SYSTEM

In considering these data, it should be noted that, although clarifier hydraulic loadings are equal on a daily basis and within the design specifications, the instantaneous hydraulic loading of the non-equalized South System was approximately twice that of the equalized North System. This may represent the most significant contribution of flow equalization to plant performance under the conditions of the study at Stouffville.

4.2 Raw Sewage Characteristics of the Equalized and Non-equalized Systems

The suspended solids and BOD contents of the two sewage streams are shown in the form of probability plots in Figures 6 and 7, respectively. There was no significant difference between the total BOD, suspended solids or phosphorus contents of the raw and equalized sewages during the fall sampling period. The average values were: total BOD_5, 148 and 142 mg/L; suspended solids, 148 and 152 mg/L; and total phosphorus, 6.4 and 6.2 mg/L, for the equalized and non-equalized systems, respectively. A difference was noted between the average soluble BOD content of the equalized system (57 mg/L) and of the non-equalized system (49 mg/L). This difference could not be substantiated statistically due to the limited data collected, but could have been caused by biological activity in the equalization tank.

The equalized sewage was consistently darker in colour and more odourous than the non-equalized sewage, suggesting anaerobic conditions in the equalization tank. This colouration persisted in the North (equalized) System's primary clarifier. Furthermore, the equalized raw sewage consistently had a lower pH (approximately 7.4) than the non-equalized sewage (approximately 8.0), a result consistent with the assumption of anaerobic activity in the equalization tank. Anaerobic degradation, which would be more evident during summer months, could create odour problems.

The filtered COD contents of samples of equalized and non-equalized sewage covering a period of about 30 hours are shown in Figure 8. Problems encountered in the 48-hour discrete sampling program due to sub-freezing temperatures resulted in a large number of missing samples. Although no definite conclusions can be drawn, it does appear that substantial concentration equalization occurred in the equalization tank. The range of filtered COD concentrations in the raw sewage was about 27 to 192 mg/L. The equalization tank resulted in a range of filtered COD concentrations from 69 to 120 mg/L.

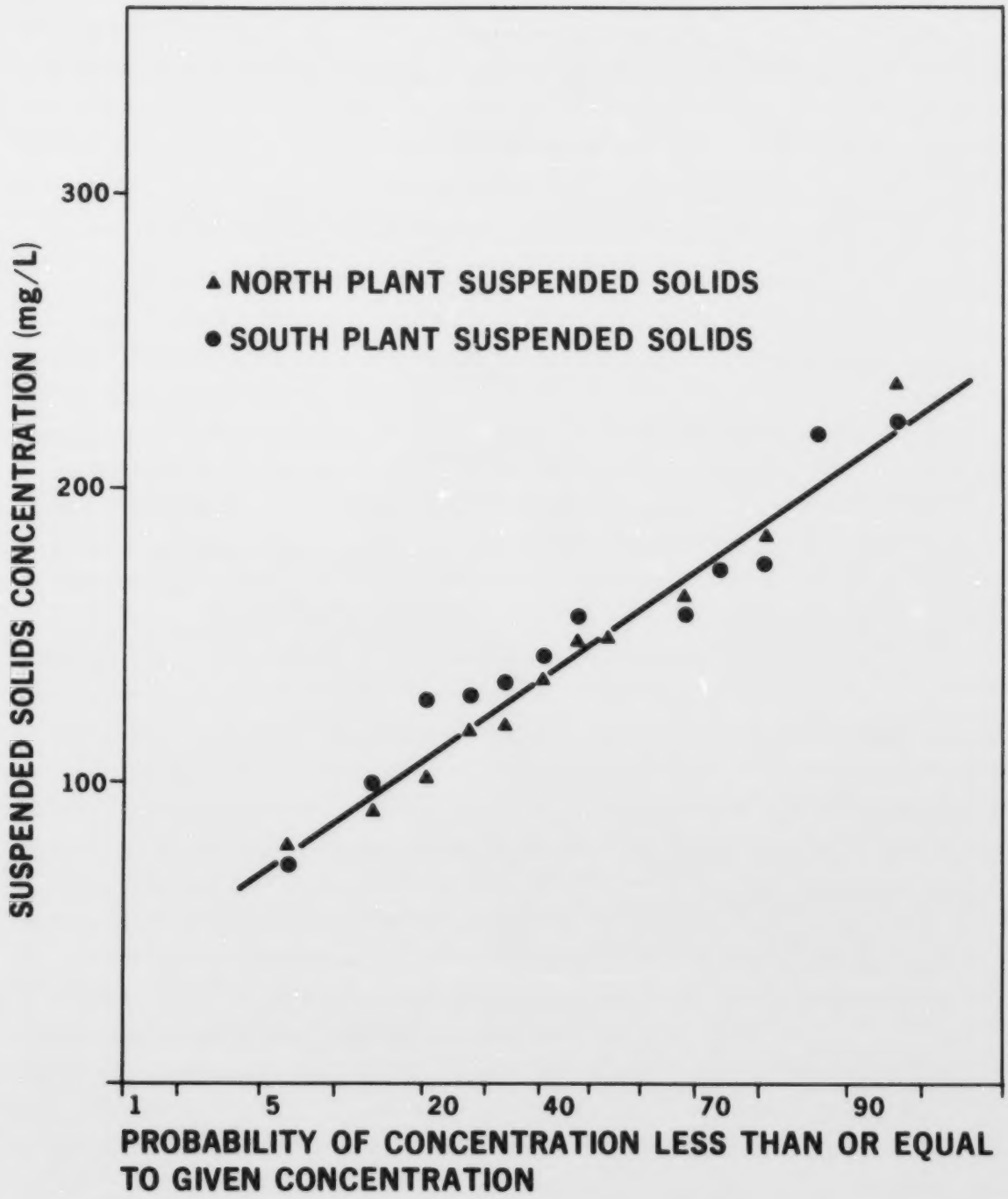

FIGURE 6 RAW SEWAGE QUALITY; SUSPENDED SOLIDS CONTENT. FALL SAMPLING

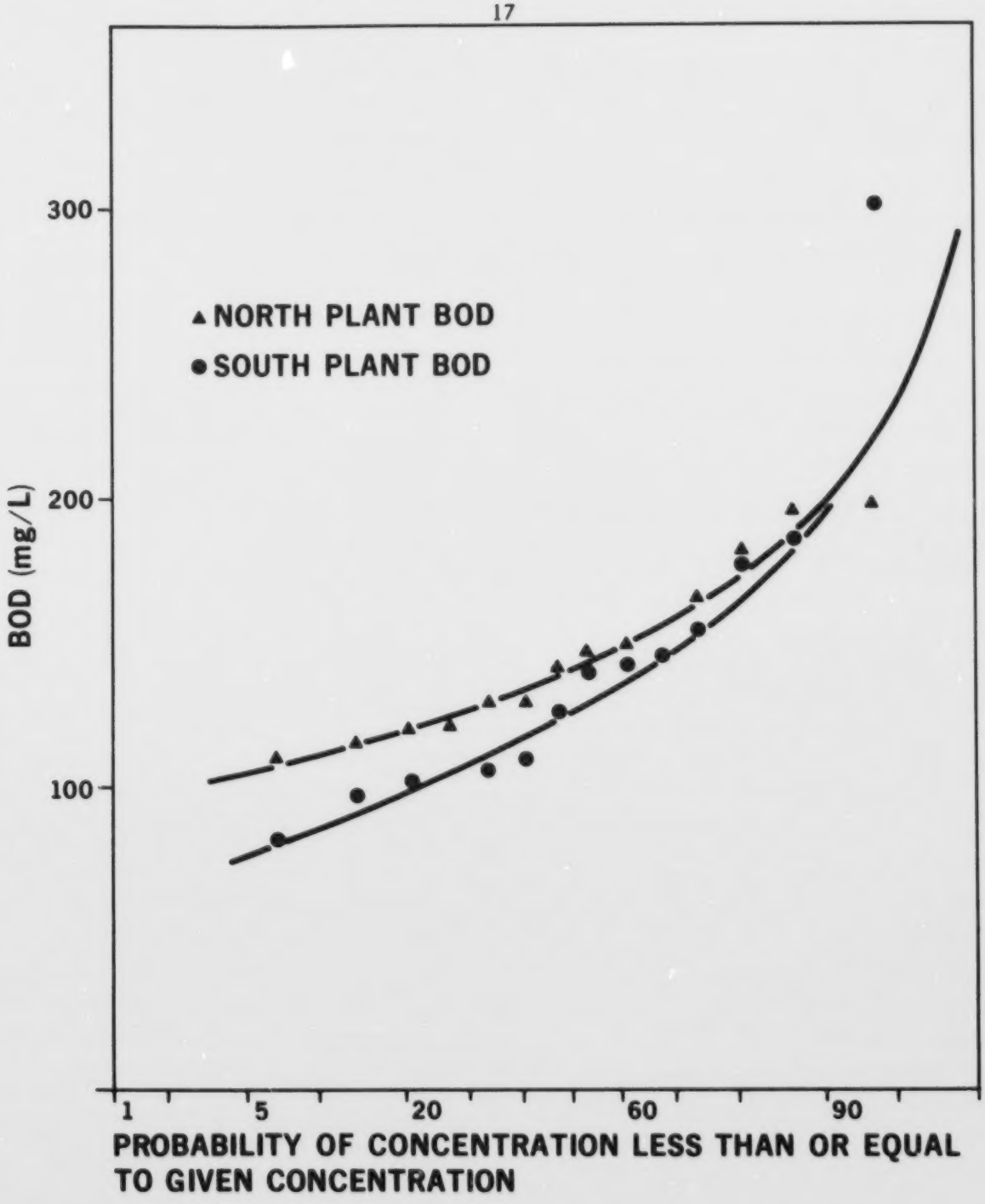

FIGURE 7 RAW SEWAGE QUALITY; BOD CONTENT. FALL SAMPLING

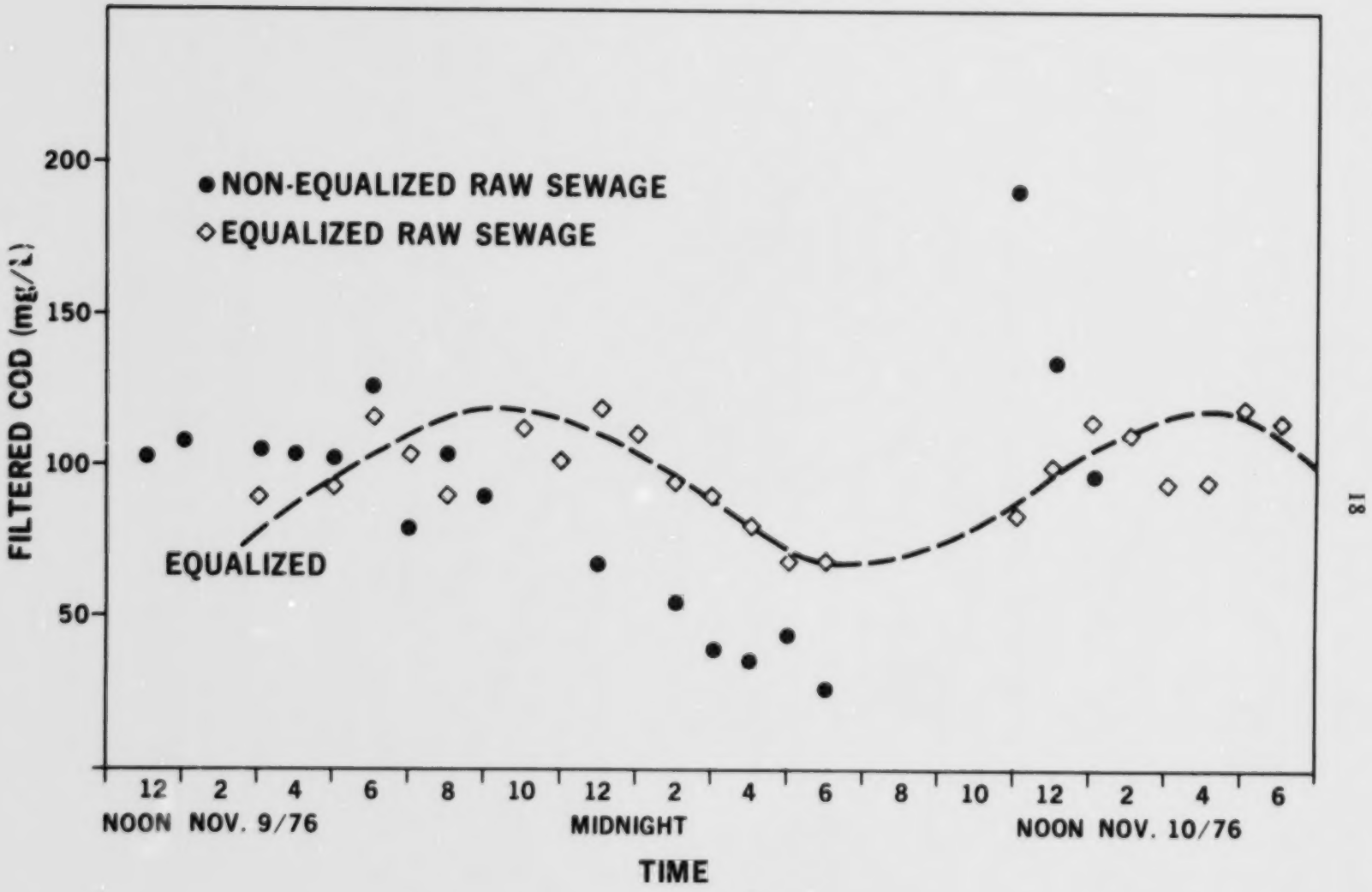

FIGURE 8 DISCRETE SAMPLING OF EQUALIZED AND NON-EQUALIZED RAW SEWAGE. FALL SAMPLING

4.3 Comparison of Primary Clarifier Performance

Probability plots of the suspended solids and BOD data are shown in Figures 9 and 10, respectively. These indicate that there was little difference in the primary effluent quality of the North and South Systems. Values for total BOD and suspended solids in the raw sewage and primary effluent, and average percentage removal of these parameters in the primary clarifiers are presented in Table 4.

TABLE 4 TOTAL BOD AND SUSPENDED SOLIDS VALUES, RAW SEWAGE AND PRIMARY EFFLUENT. FALL SAMPLING

	North System (Equalized)		South System (Non-equalized)	
	Total BOD	Suspended Solids	Total BOD	Suspended Solids
Raw Sewage				
Average Values:	148	148	142	152
Range (mg/L):	111 - 198	80 - 236	84 - 300	75 - 222
Primary Effluent				
Average Values:	129	116	118	108
Range (mg/L):	80 - 163	70 - 194	75 - 186	62 - 178
Primary Clarifier:				
Average Removal (%)	12.8	21.6	16.9	28.9

The most significant impact of the on-off operation of the main lift pump feeding the non-equalized South System and the high instantaneous loading should be on the operation of the clarifiers. However, the non-equalized South System's primary clarifier appeared to operate, on the average, more efficiently in terms of total BOD and suspended solids removal than the equalized North System's clarifier, despite an instantaneous hydraulic loading of 68.5 $m^3/d \cdot m^2$ as compared to 34.3 $m^3/d \cdot m^2$.

The efficiencies of the primary clarifiers in both the equalized and non-equalized systems were relatively low. The raw sewage exhibited typical settling properties under quiescent conditions. Half-hour settling tests provided BOD removals averaging 25 percent and suspended solids removals of approximately 60 percent.

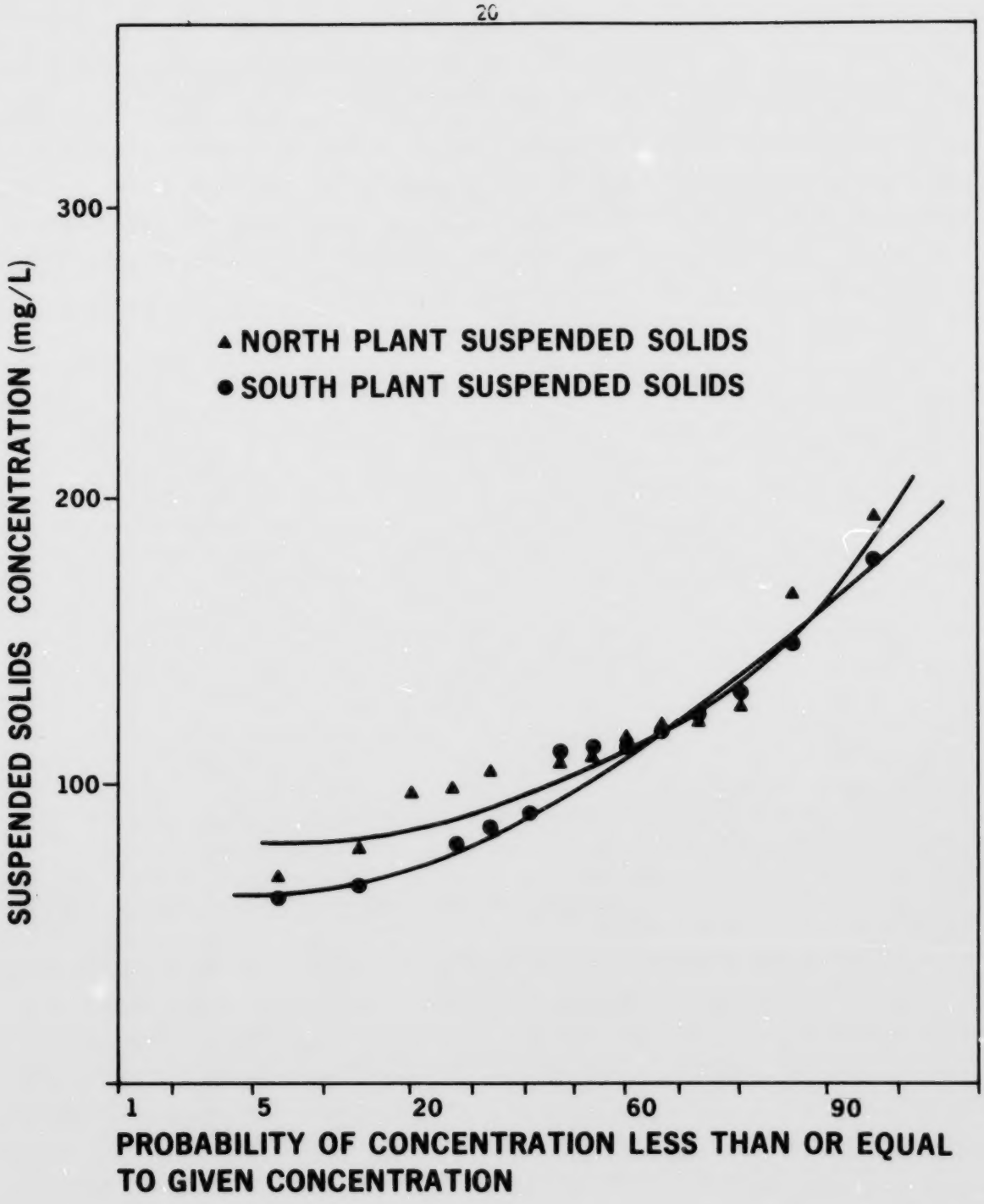

FIGURE 9 PRIMARY EFFLUENT QUALITY; SUSPENDED SOLIDS CONTENT. FALL SAMPLING

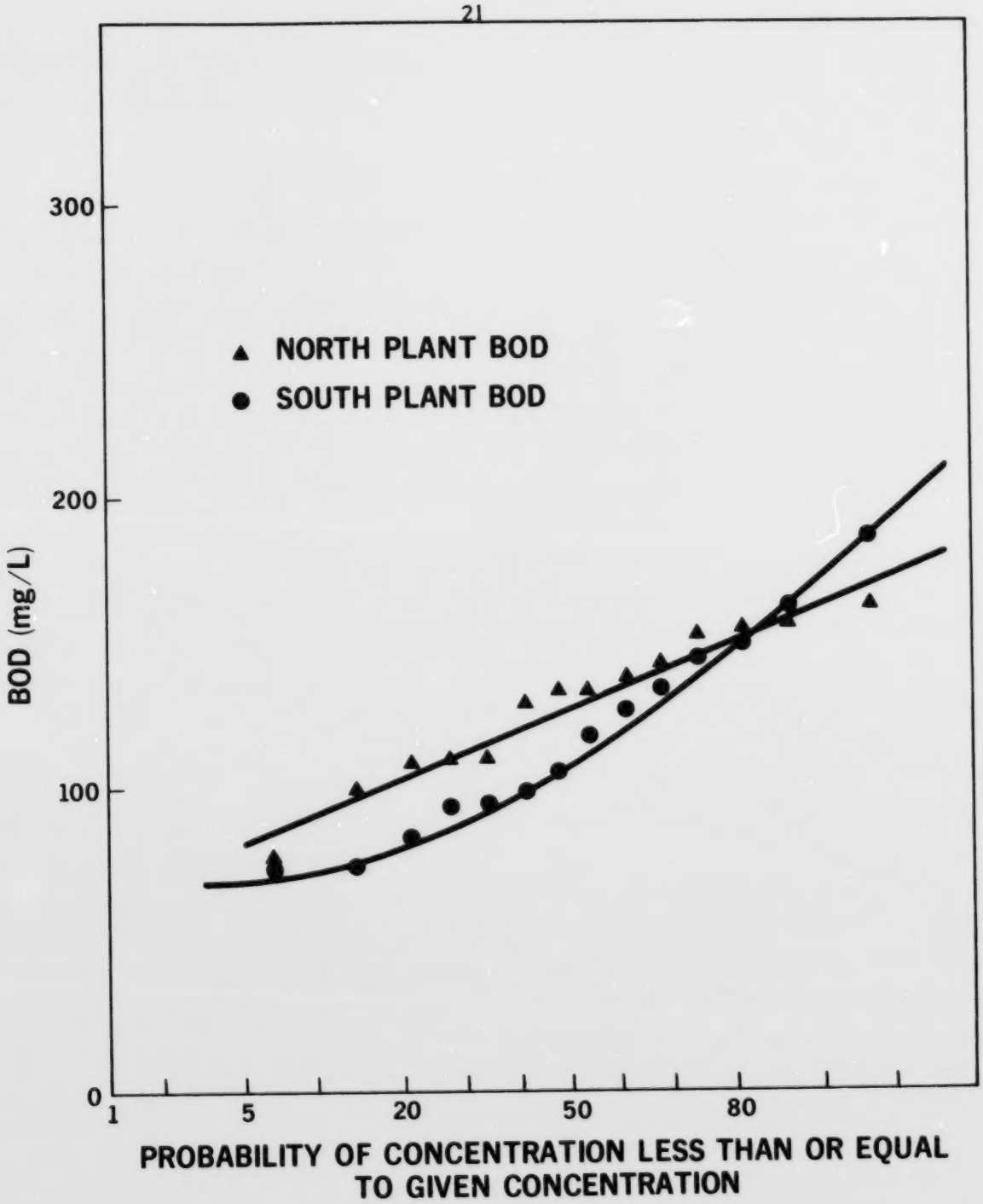

FIGURE 10 PRIMARY EFFLUENT QUALITY; BOD CONTENT. FALL SAMPLING

However, the clarifier design resulted in high weir loadings and the possibility of short-circuiting due to poor flow distribution.

4.4 Comparison of Secondary Treatment Performance

Operating conditions in the North and South Systems are summarized in Tables 5 and 6, respectively. The temporal variations in mixed liquor concentrations for both systems are shown in Figure 11.

During the initial five weeks of the study program, the aeration tank mixed liquor concentrations were maintained approximately equal in the two systems, at about 2000 mg/L. However, at the beginning of December, excessive wastage from the North System reduced the mixed liquor concentration to about 1400 mg/L. It appears that about December 9, the plant was subjected to some type of shock which affected both systems. The North System was more severely affected. Losses of solids in the effluent resulted in the mixed liquor concentration dropping to less than 500 mg/L in the North System, although wasting of activated sludge was stopped on December 10. The North System was seeded with aerobic digester sludge from a nearby plant on December 20 to increase the MLSS to 2300 mg/L. The North System's aeration tank during this period appeared greyish in colour and anaerobic odours were evident despite relatively high dissolved oxygen concentrations (0.9 to 5.2 mg/L). Some effect on the South System was evident in the deteriorating sludge settleability, however, the impact on that system was much less severe probably due to higher MLSS concentrations at the time of the shock.

Operating variables in the North and South systems were maintained in similar ranges during the weeks prior to the upset (Tables 5 and 6). The biomass in the South System, however, seemed to exhibit slightly better settling properties. The improved settleability was not evident in the effluent suspended solids results because of the higher instantaneous hydraulic loading of the South System's secondary clarifier.

The secondary effluent quality data for the North and South Systems are summarized in Table 7. Suspended solids and total BOD data for the two systems are presented in the form of probability graphs in Figures 12 and 13, respectively. Data obtained after the plant upset were excluded because it was felt that this period was not representative of normal operation of the systems. The earlier data show that the North System consistently produced an effluent of better quality in terms of total BOD and suspended solids than the non-equalized system. However, removal of soluble BOD by the biomass was unaffected by the operating mode.

TABLE 5 SECONDARY TREATMENT OPERATING CONDITIONS. EQUALIZED NORTH SYSTEM. FALL SAMPLING

	Flow (m^3/d)	MLSS (mg/L)	Sludge Settleability (%)	Aeration Tank Dissolved Oxygen (mg/L)	Oxygen Uptake Rate (mg/L•h)	Organic Loading (kg BOD/kg MLSS•d)
Prior to Upset (38 days)						
Average:	1012	1776	47	4.7	19.7	0.26
Range:	874 - 1168	1270 - 2194	25 - 90	3.0 - 6.2	18.0 - 21.0 (4 results)	0.17 - 0.35 (9 results)
After Upset (16 days)						
Average:	1049	1394	13	4.0	18.0	0.68
Range:	840 - 1225	456 - 2716	2 - 35	0.5 - 5.4	(1 result only)	0.16 - 1.29 (4 results)
Overall						
Average:	1023	1646	37	4.5	19.4	

TABLE 6 SECONDARY TREATMENT OPERATING CONDITIONS. NON-EQUALIZED SOUTH SYSTEM. FALL SAMPLING

	Flow (m^3/d)	MLSS (mg/L)	Sludge Settleability (%)	Aeration Tank Dissolved Oxygen (mg/L)	Oxygen Uptake Rate (mg/L•h)	Organic Loading (kg BOD/kg MLSS•d)
Prior to Upset (38 days)						
Average:	1025	2031	27	4.5	19.1	0.19
Range:	890 - 1305	1580 - 2734	12 - 55	2.6 - 6.0	15.0 - 22.0 (4 results)	0.41 - 0.36 (10 results)
After Upset (16 days)						
Average:	992	2309	51	3.8	24.0	0.20
Range:	857 - 1174	2000 - 2624	27 - 80	0.9 - 5.2	(1 result)	0.16 - 0.24 (4 results)
Overall						
Average:	1015	2125	34	4.3	20.0	0.19

TABLE 7 SECONDARY EFFLUENT QUALITIES. FALL SAMPLING

	Contaminant Concentration (mg/L)									
	Equalized North System					Non-equalized South System				
	BOD		Suspended	Phosphorus (P)		BOD		Suspended	Phosphorus (P)	
	Total	Soluble	Solids	Total	Soluble	Total	Soluble	Solids	Total	Soluble
Prior to Upset										
Average:	13	6	16	1.2	0.6	28	6	28	1.1	0.6
Range:	8 - 27	4 - 9	8 - 21	0.5 - 1.4	0.4 - 0.8	15 - 42	3 - 11	16 - 49	0.4 - 1.6	0.3 - 1.1
After Upset										
Average:	39	16	31	1.8	0.4	31	7	19	1.1	0.3
Range:	25 - 51	14 - 17	15 - 48	1.5 - 2.3	0.3 - 0.5	11 - 40	5 - 9	5 - 33	0.3 - 2.0	0.1 - 0.5
Overall										
Average:	21	8	20	1.3	0.5	29	6	26	0.9	0.5

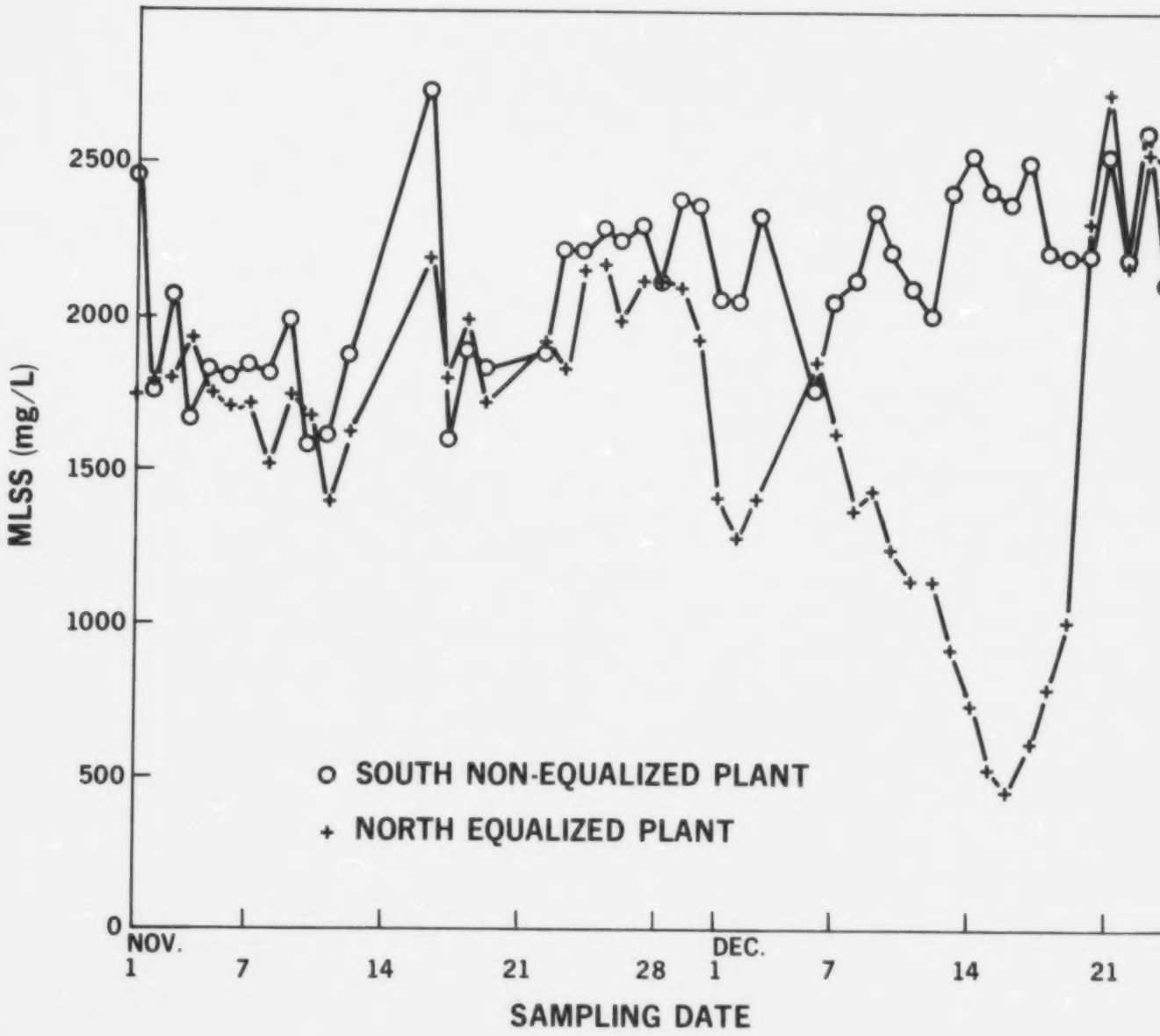

FIGURE 11 MLSS VARIATIONS. FALL SAMPLING

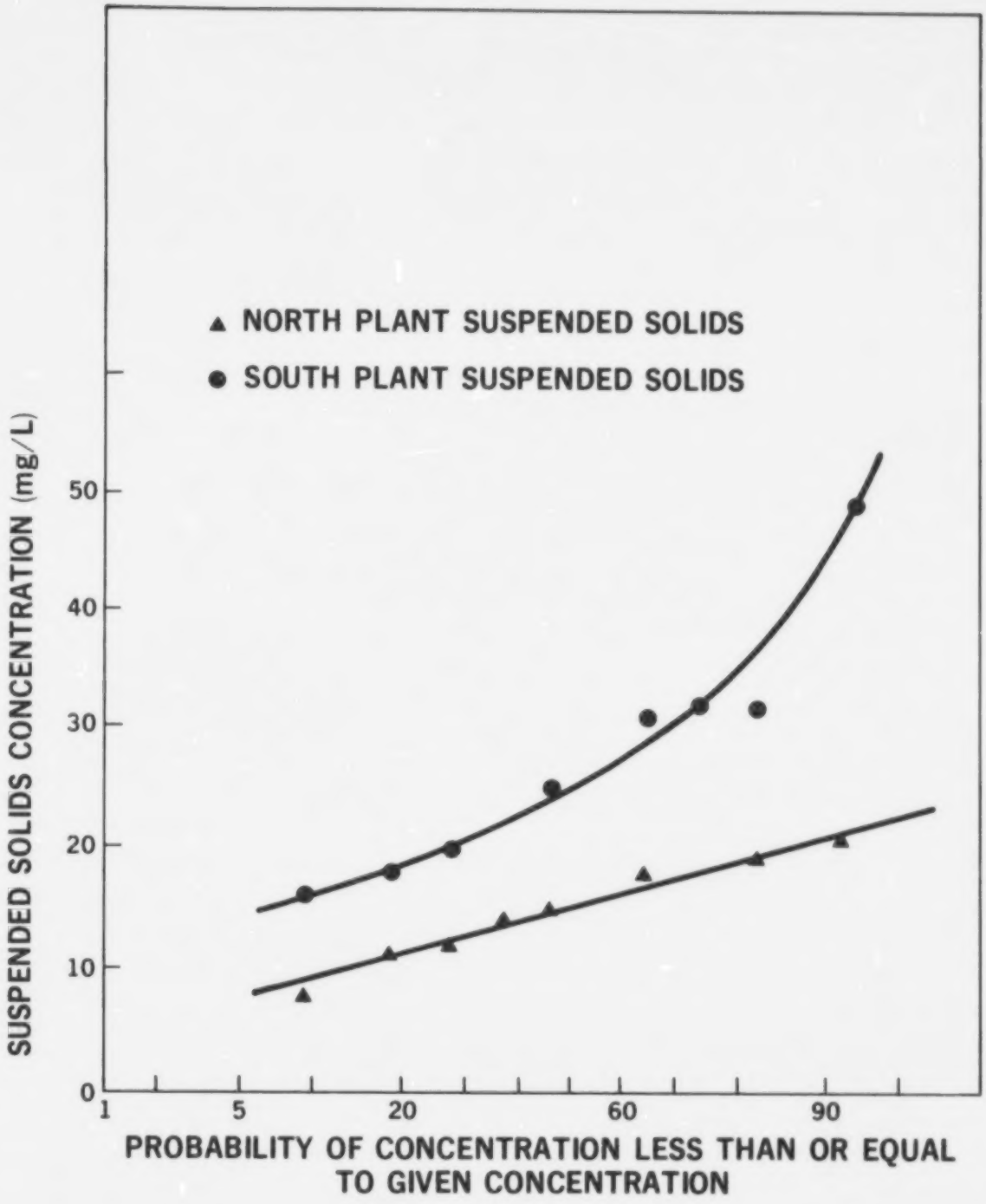

FIGURE 12 SECONDARY EFFLUENT QUALITY; SUSPENDED SOLIDS CONCENTRATION. FALL SAMPLING, EXCLUDING DATA FROM PLANT UPSET PERIOD

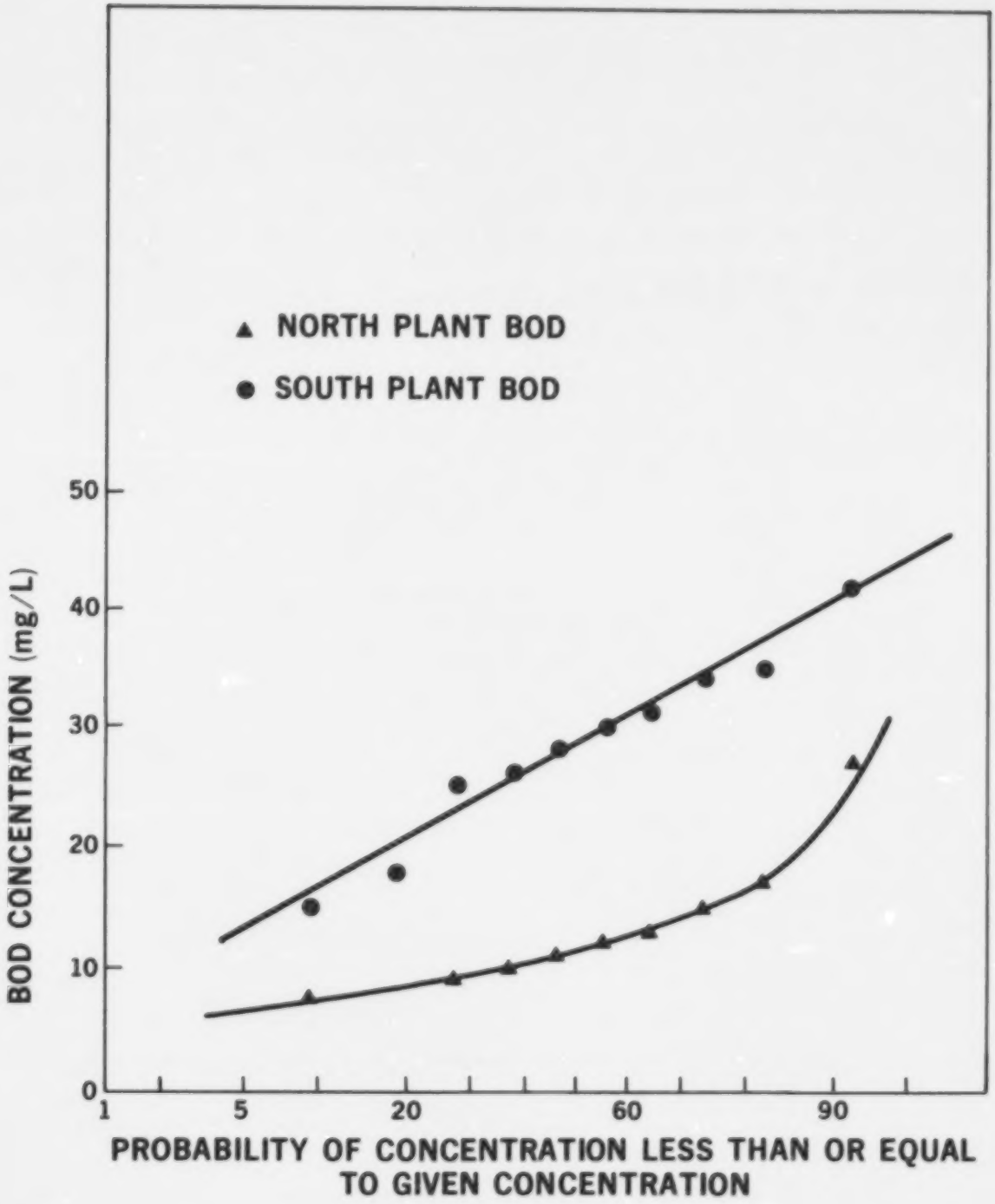

FIGURE 13 SECONDARY EFFLUENT QUALITY; BOD CONCENTRATION. FALL SAMPLING, EXCLUDING DATA FROM PLANT UPSET PERIOD

The phosphorus removal efficiency was also relatively unaffected by flow equalization. At present, Stouffville utilizes waste pickle liquor containing approximately five percent Fe for phosphorus removal. An average dosage of 11 mg/L Fe was applied to both systems during the study period.

4.5 Comparison of Relative Sludge Production Rates

At the Stouffville plant, settled activated sludge is removed from the secondary clarifiers by an air lift system. Excess sludge is wasted continuously to the primary clarifiers by means of an adjustable gate in a splitter box. Daily wastage rates to the primary clarifiers were estimated from the approximate air lift pump capacity, the percentage of the sludge flow diverted to the primary clarifier and the average measured sludge concentration.

Sludge was pumped individually from each primary clarifier to the single anaerobic digester by means of a centrifugal sludge pump. Sludge pumping is a manual operation carried out twice a day. Total sludge volume pumped from each plant was monitored by the volume change in the digester. Grab samples of primary clarifier sludge were collected for total solids determination.

Extremely cold weather in the second half of December caused the floating roof of the digester to freeze. Waste sludge volumes for the last week of the study could not therefore be measured. These problems, along with the upset experienced in the secondary section of the plant, limit the amount of dependable sludge data obtained during the fall monitoring period.

There was no significant difference between the quantities of sludge removed from the two systems. The manual pumping operation resulted in excessive volumes of sludge pumped to prevent any accumulation of solids in the clarifiers. Solids concentrations of the sludges were therefore relatively low. The average quantities of sludge pumped daily from the two primary clarifiers are summarized in Table 8.

A sludge balance carried out for the two sections of the Stouffville plant indicated that the quantities of solids removed daily from the plant, including losses in the effluent, were as follows: 236 kg/d from the equalized North System and 254 kg/d from the non-equalized South System. Approximately 182 kg/d of solids were wasted to the primary clarifiers from each biological system. A substantial proportion of these solids were particulate matter that should have been removed in the primary treatment process. The low primary clarifier efficiency resulted in recirculation of these solids

TABLE 8 SLUDGE PUMPED DAILY FROM PRIMARY CLARIFIERS. FALL SAMPLING*

Plant	Sludge Volume (L/m^3)	Sludge Concentration (% Solids)	Quantity of Waste Solids (g/m^3)
North System (Equalized)	17.5	1.22	213
South System (Non-equalized)	14.2	1.55	220

* Rates of sludge wastage are in agreement with similar data developed at the Stouffville plant during the phosphorus removal study carried out in 1975.

within the system. The quantity of waste activated sludge from the two systems, including solids from the phosphorus removal process, was approximately equal.

5 RESULTS OF SPRING 1977 MONITORING

Capital costs estimates for the Stouffville Water Pollution Control Plant indicated that the equalization tank and appurtenances, including sludge scraping equipment, represented in the range of 10 to 20 percent of the total capital cost of the treatment works. The spring monitoring program was designed to determine if this capital cost could be recovered by increasing the capacity of the system by a proportional amount without sacrificing effluent quality. An increase in hydraulic loading of 15 percent was selected for this phase of the study. This is not, however, necessarily the maximum flow that could be successfully treated in the plant under equalized conditions.

The parallel treatment systems were monitored intensively for a seven-week period in March, April and May 1977. The plant configuration and basic sampling and analytical program during the spring 1977 monitoring were similar to the program carried out during the fall of 1976.

5.1 Treatment Plant Hydraulic Loadings

The spring sampling program was carried out during a period of high sewer infiltration. Raw sewage flows increased significantly over the dry weather flows experienced during the fall of 1976. Thus, adequate flow was available to allow operation of the equalized plant under constant flow conditions for virtually 24 hours a day.

The distribution of daily mean flows to the North and South Systems during the spring program is shown in Figure 14, and the average and range of flow conditions are summarized in Table 9.

The flow of raw sewage from the wet well was adjusted such that the North System was hydraulically loaded approximately 15 percent higher than the South System. (The North System's flow was about 7.5 percent higher than the average North-South daily flow, while the South System's flow was 7.5 percent lower.) Almost daily adjustments to the flows were required to compensate for variations in the daily flow and the volume of sewage stored in the equalization tank.

Flows in excess of the capacity of the North System's feed pump were encountered from April 1 to April 12. The desired incremental flow to the equalized plant could not be maintained and sampling was discontinued until the raw sewage flow declined to a more manageable level. The equalization tank overflowed and bypassed the treatment system during much of this period. Maximum daily flows were in excess of 3180 m^3/d as compared to the maximum daily flow of 2400 m^3/d during the fall

TABLE 9 RAW SEWAGE FLOWS TO EQUALIZED AND NON-EQUALIZED SYSTEMS. SPRING SAMPLING

Flow Variable	North System (Equalized)	South System (Non-equalized)
Average Daily Flow:	1401	1201
Range (m^3/d):	1074.8 - 1692.1	894.8 -1786.2
Average Pumping Time:	23.6	13.3
Range (hours):	20.3 - 24.0	10.0 - 18.2
Average Instantaneous Loading* (m^3/min)	0.99	1.47

* The average instantaneous loading represents the average delivery rate when pump is operating, averaged over entire spring sampling period. Instantaneous loading varied on a daily basis depending on total raw sewage flow, pumping time and level in equalization tank.

sampling period and the design flow of 2200 m^3/d. The instantaneous flow to the North System varied over a wide range during the study from 0.76 m^3/min to 1.26 m^3/min. The South System's instantaneous flow was maintained relatively constant over a range from 1.40 m^3/min to 1.60 m^3/min. The instantaneous loading of the North System was significantly higher during the spring sampling than during the fall period. The range of secondary clarifier loadings on the North System was from approximately 24 to 44 $m^3/m^2 \cdot d$, averaging 34 $m^3/m^2 \cdot d$. The South System's peak clarifier loadings were somewhat lower than during the fall, averaging 51 $m^3/m^2 \cdot d$ during pumping cycles.

To illustrate the effectiveness of flow equalization, a high flow day and a low flow day were analyzed to indicate the range of conditions experienced during the spring sampling period. Diurnal flow curves for the North and South Systems for these two days are presented in Figure 15 (April 1) and Figure 16 (April 29). In both cases, flow to the North System was constant throughout the day. The variation between maximum hourly and minimum hourly flow (1.9, on April 1; 2.2, on April 29) was eliminated by the equalization process.

The secondary clarifier loadings for the spring 1977 sampling period are summarized in Table 10. Loadings based on average daily flow, maximum daily flow and maximum hourly flow were as high or higher in the North System than in the South System. Further, the difference between instantaneous loadings on the North and South

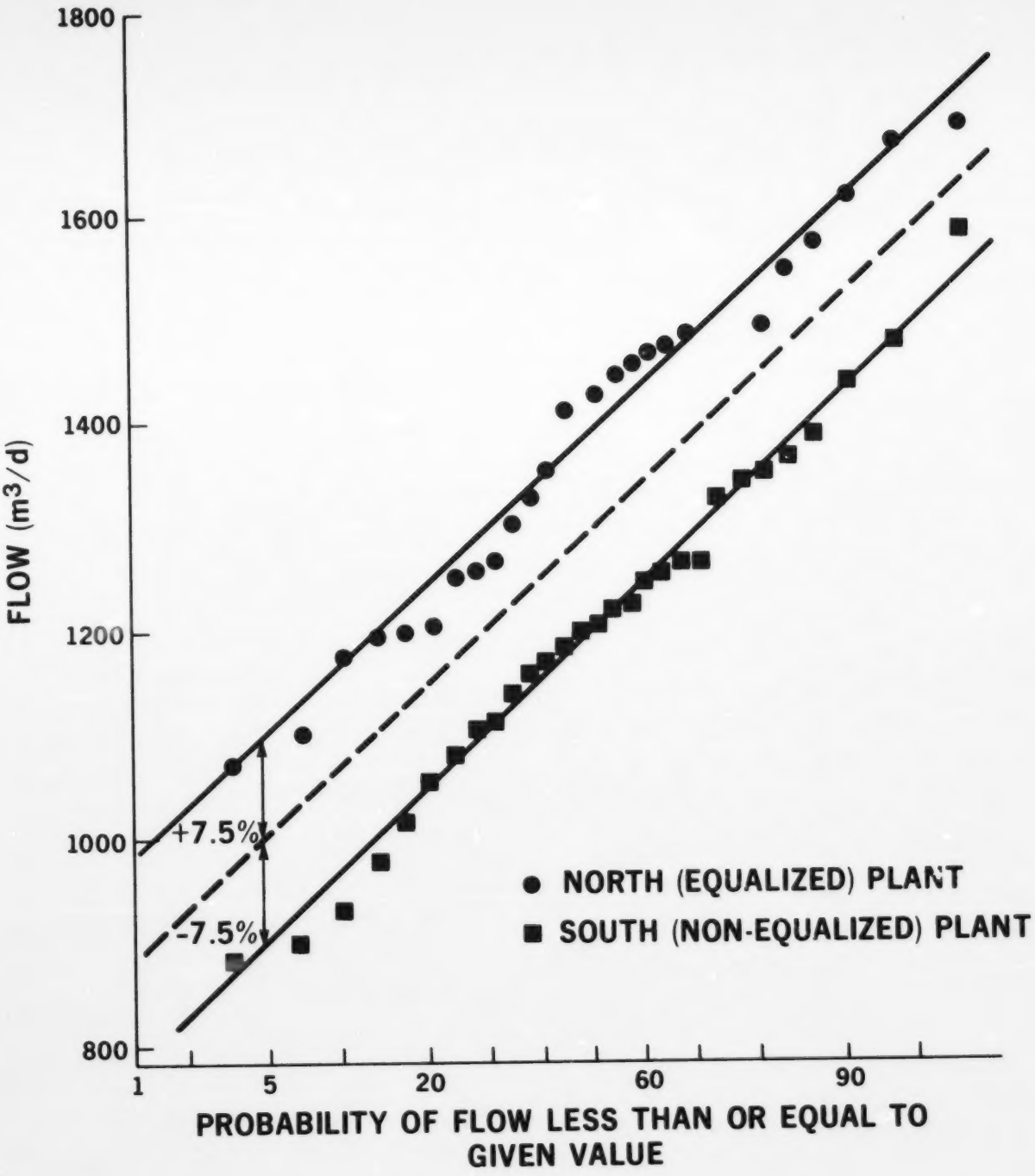

FIGURE 14 DAILY RAW SEWAGE FLOWS. SPRING SAMPLING

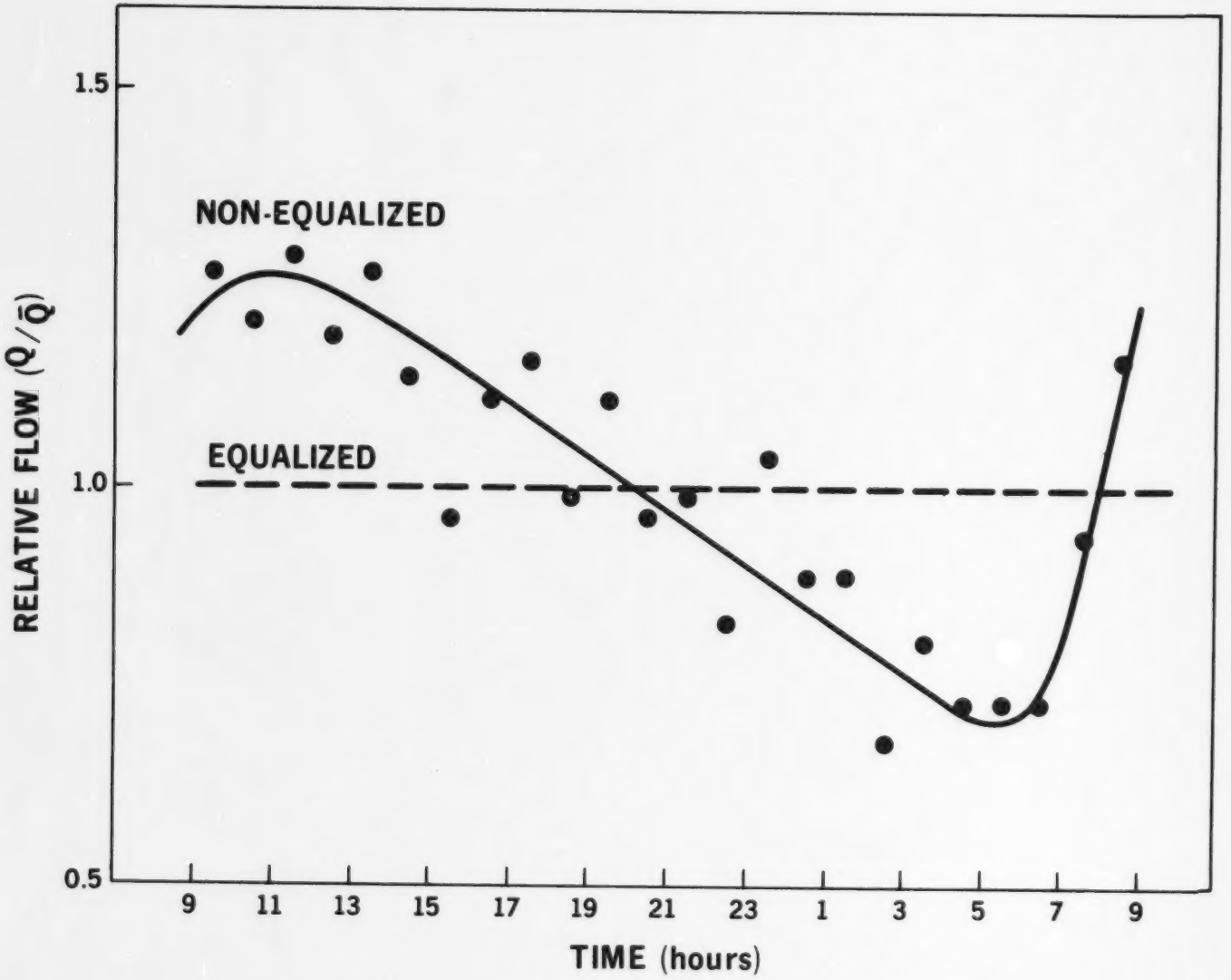

FIGURE 15 EFFECT OF FLOW EQUALIZATION ON DIURNAL FLOW VARIATION. APRIL 1, 1977

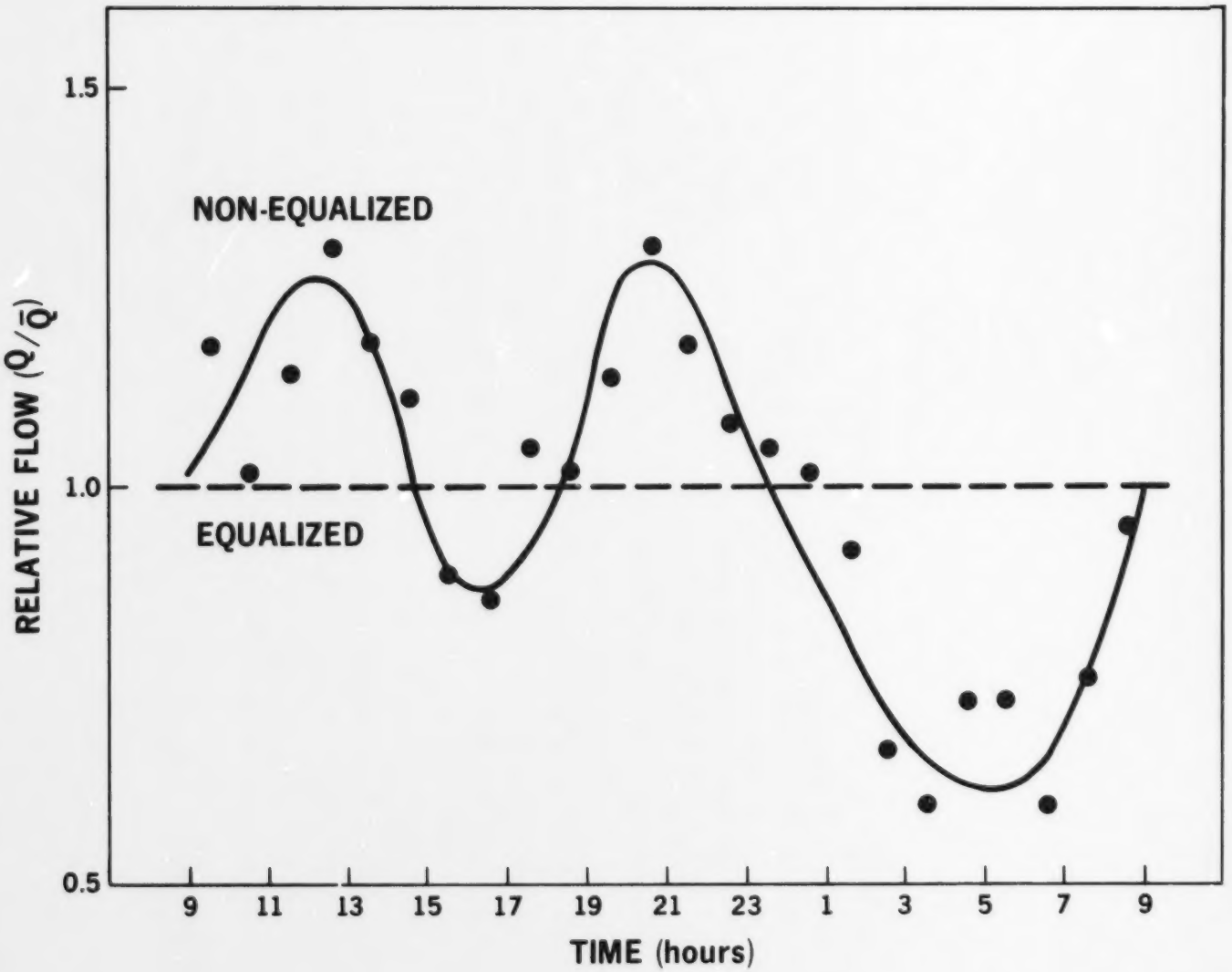

FIGURE 16 EFFECT OF FLOW EQUALIZATION ON DIURNAL FLOW VARIATION. APRIL 29, 1977

TABLE 10 SECONDARY CLARIFIER LOADINGS. SPRING SAMPLING

	Secondary Clarifier Loading ($m^3/m^2 \cdot d$)	
	South System (Non-equalized)	North System (Equalized)
Average Daily Flow	28.40	33.05
Instantaneous Peak Flow	53.86	42.60
Maximum Daily Flow	37.70	42.60
Maximum Hourly Flow (estimated)	42.60	42.60

systems' secondary clarifiers were less during the spring than during the fall monitoring period.

5.2 Raw Sewage Characteristics of the Equalized and Non-equalized Systems

The suspended solids and BOD content of the two sewage streams are shown in the form of probability plots in Figures 17 and 18, respectively. As in the fall monitoring period, there was no significant difference between the contaminant content of the raw sewage to the North and South Systems. The average values were: total BOD 103 and 111 mg/L; suspended solids 144 and 149 mg/L; total phosphorus 5.41 and 5.76 mg/L and soluble phosphorus 3.14 and 3.39 mg/L for the equalized and non-equalized systems, respectively.

The high infiltration during the spring resulted in a dilution of raw sewage BOD (i.e. compared to the dry weather concentration). The increase in soluble BOD in the equalized raw sewage noted in the fall sampling program was not confirmed during the spring sampling. (Average soluble BOD values in the spring were: 35 and 42 mg/L for the equalized and non-equalized systems, respectively). The average soluble BOD content of the two streams for the combined fall 1976 and spring 1977 sampling were virtually identical, each approximately 46 mg/L. It appears that storage resulting from flow equalization does not affect the chemical quality of the raw sewage in terms of any of the parameters analyzed.

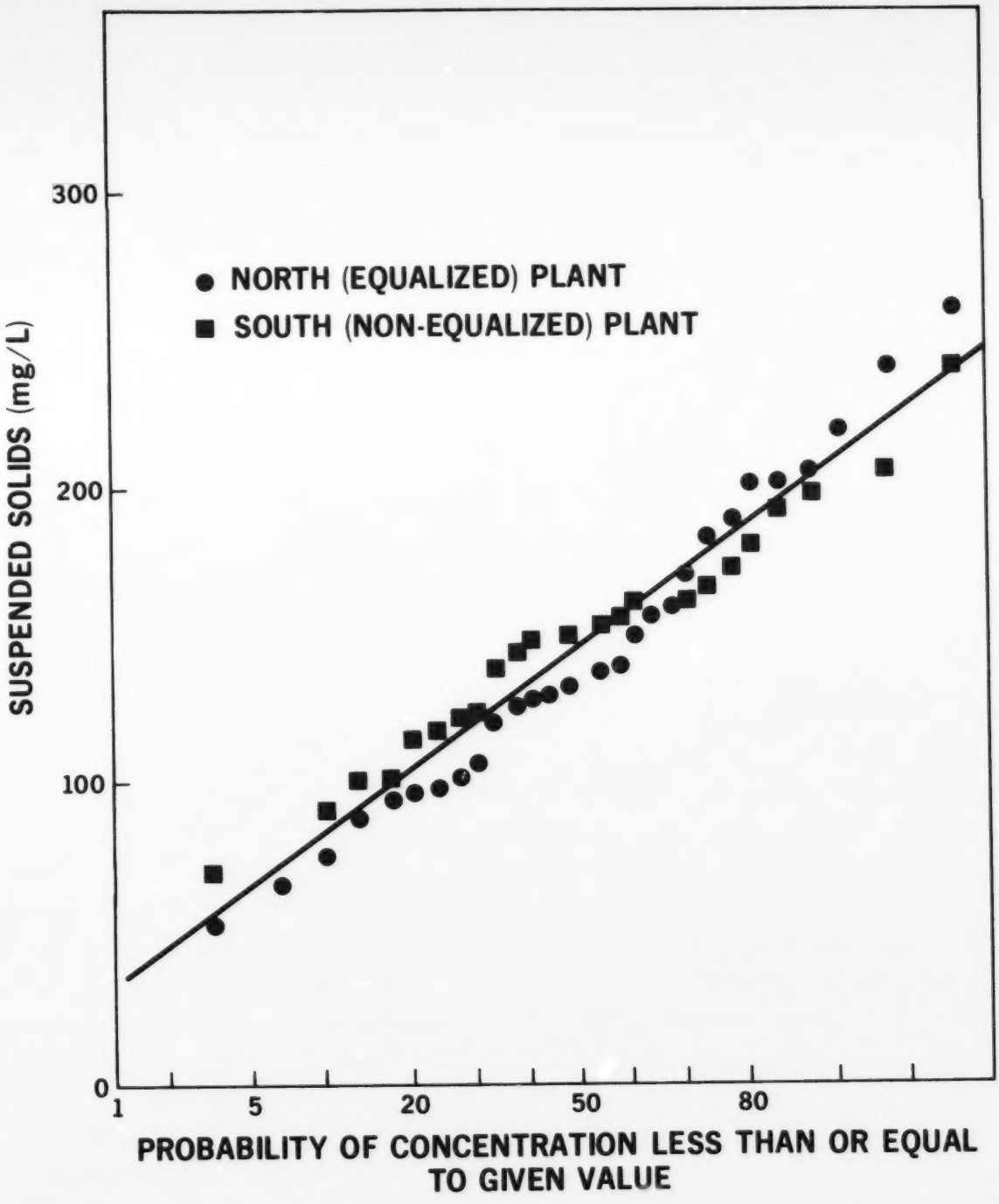

FIGURE 17 RAW SEWAGE QUALITY; SUSPENDED SOLIDS CONTENT. SPRING SAMPLING

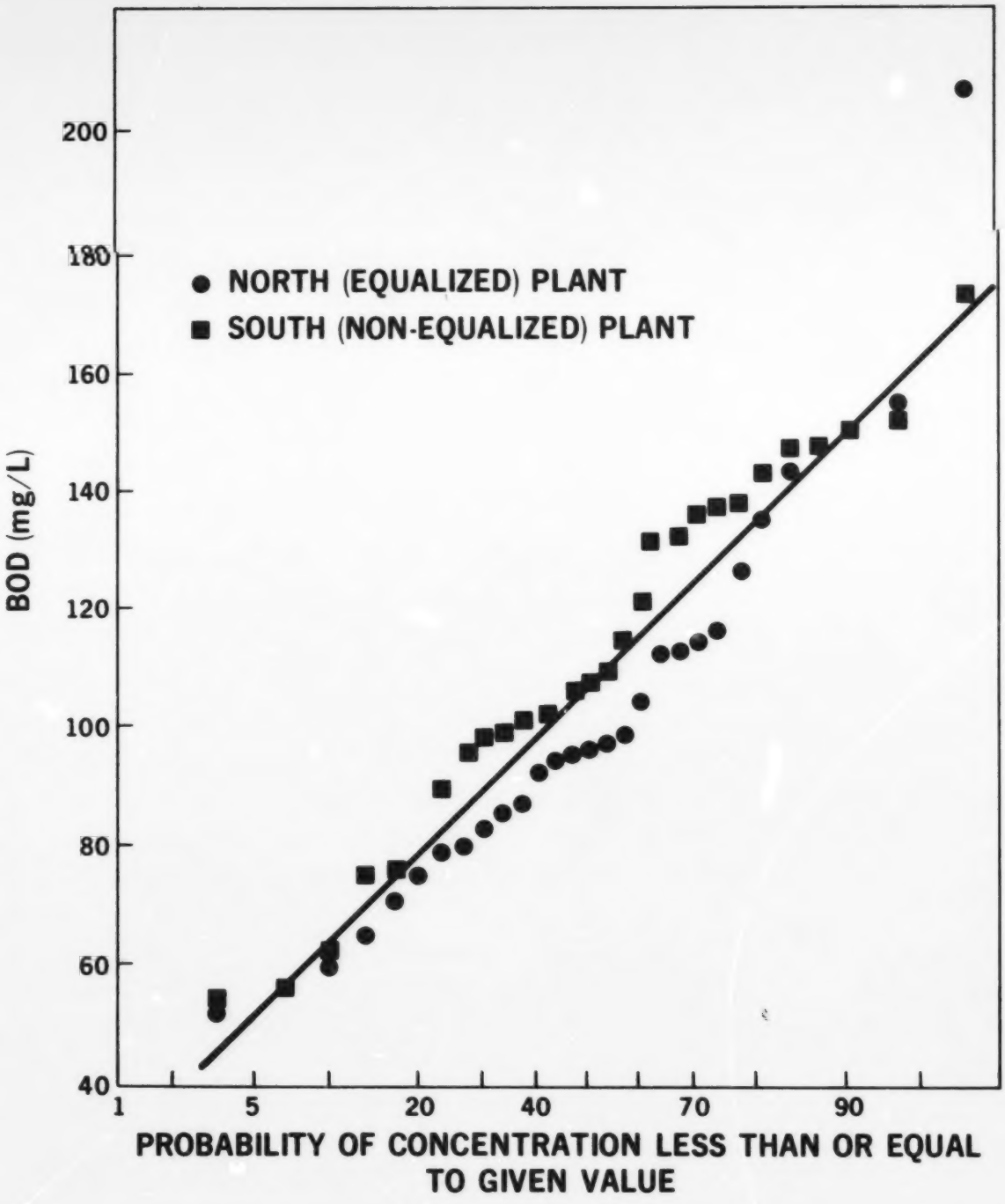

FIGURE 18 RAW SEWAGE QUALITY; BOD CONTENT. SPRING SAMPLING

The sewage leaving the equalization tank and entering the North System was darker in colour during the fall than during the spring sampling period. Odours were less noticeable in the spring, however, despite warmer weather. Some darkening of the primary clarifier and aeration tank contents was also evident in the spring but the differences between the equalized and non-equalized systems were not as noticeable as during the fall. It is likely that the increase in flow and consequent reduction in storage times in the equalization tank, along with dilution of the sewage due to infiltration, more than compensated for the increased biological activity resulting from the higher temperatures. More severe odour problems in the area of the equalization tank would occur as a result of excessive storage under higher ambient temperatures during dry weather flows in summer months.

5.3 Comparison of Primary Clarifier Performance

Probability plots of the suspended solids and BOD contents of the primary effluents are shown in Figures 19 and 20, respectively. The analytical results of the spring sampling program are summarized in Table 11.

There was no significant difference between the primary effluent from the North System and the South System. Despite the increased hydraulic loading of the plant (cf. the fall program) and the increased load carried by the North System in comparison to the South System, there was no significant difference between the primary effluent of the two systems; neither could a deterioration of primary clarifier performance in the North System (as measured by settling properties and sludge thickening parameters) be detected. Occasional high suspended solids concentrations were noted in the non-equalized system's primary effluent, although these high results could not be correlated with high daily flows or higher than normal instantaneous loadings to the South System.

Average raw sludge solids concentrations from the primary clarifiers were 2.36% and 2.27% for the North and South Systems, respectively. The increased daily loading to the equalized plant did not affect the settling properties in the clarifier based on any of the parameters monitored. Conversely, the effect of higher instantaneous loading of the non-equalized plant could not be detected.

5.4 Comparison of Secondary Treatment Performance

The operating conditions in the North and South Systems are summarized in Table 12, and the temporal variations in mixed liquor concentrations for the two systems are shown in Figure 21.

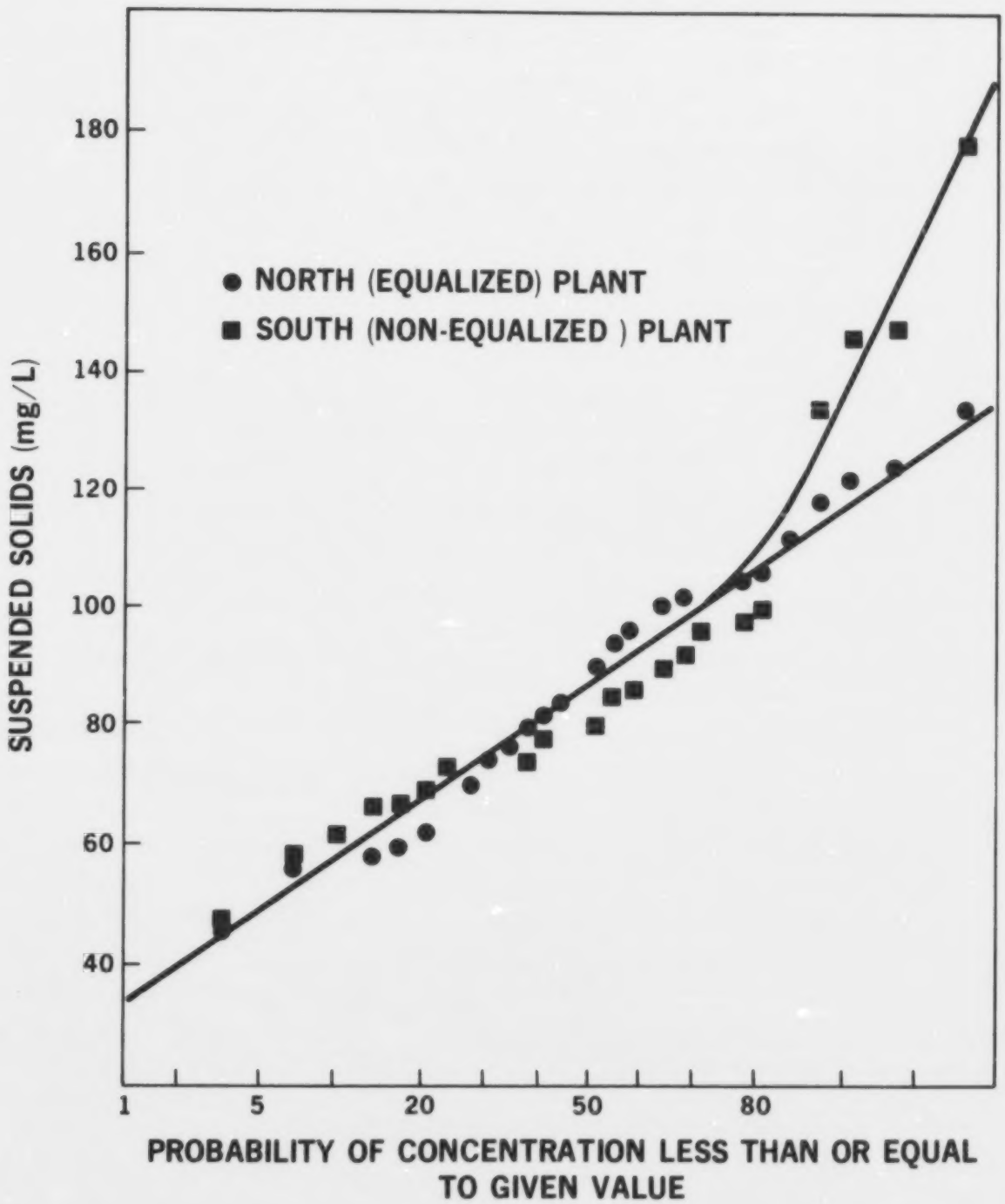

FIGURE 19 PRIMARY EFFLUENT QUALITY; SUSPENDED SOLIDS CONTENT. SPRING SAMPLING

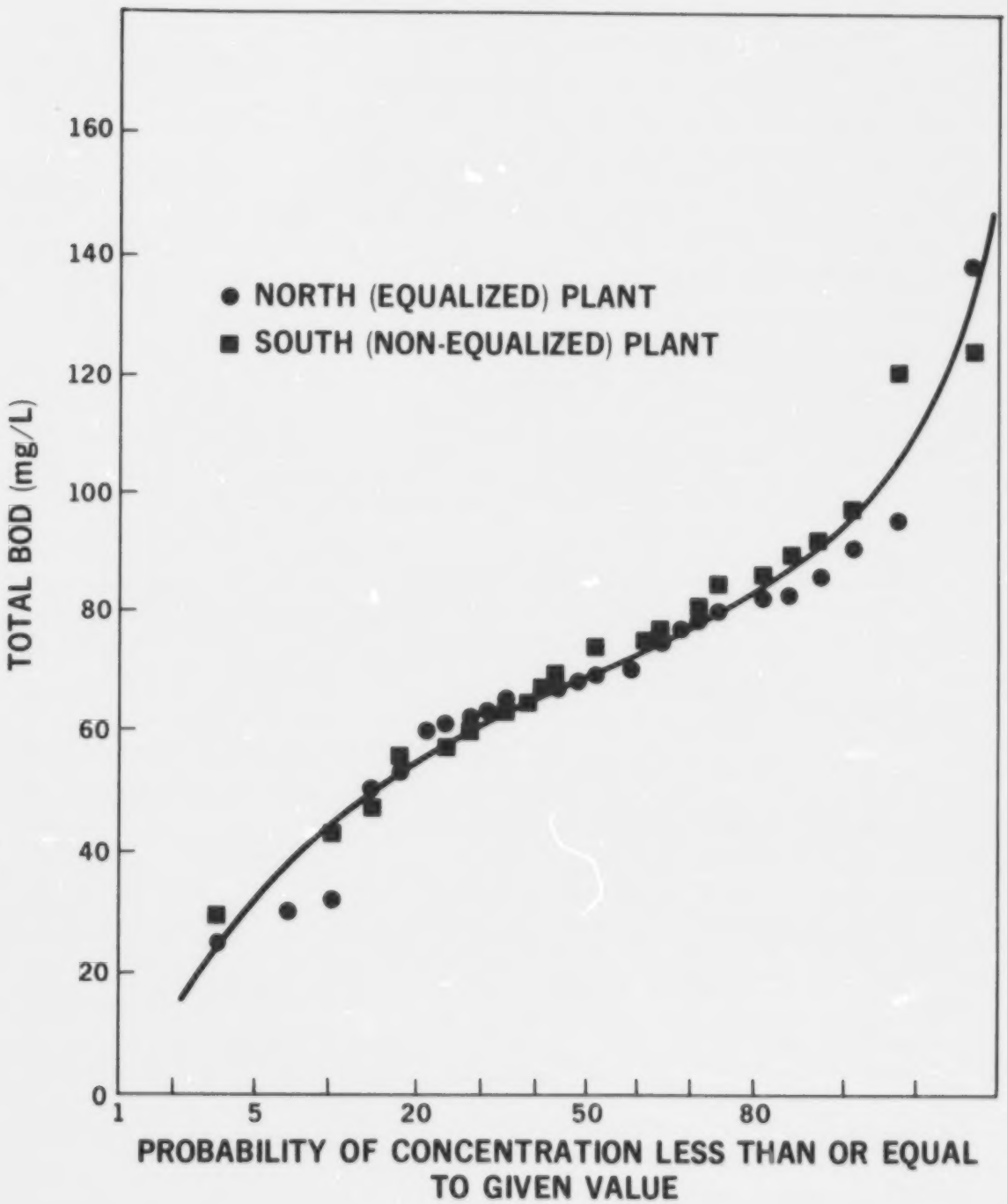

FIGURE 20 PRIMARY EFFLUENT QUALITY; BOD CONTENT. SPRING SAMPLING

TABLE 11 RAW SEWAGE AND PRIMARY EFFLUENT TOTAL BOD, SUSPENDED SOLIDS AND TOTAL PHOSPHORUS. SPRING SAMPLING

	North System (Equalized)			South System (Non-equalized)		
	Total BOD	Suspended Solids	Total Phosphorus as (P)	Total BOD	Suspended Solids	Total Phosphorus as (P)
Raw Sewage						
Average Values:	103	144	5.41	111	149	5.76
Range (mg/L):	60 - 206	58 - 264	2.64 - 9.04	53 - 173	70 - 242	2.01 - 9.90
Primary Effluent						
Average Values:	70	89	3.58	72	91	3.27
Range (mg/L):	25 - 139	46 - 134	3.07 - 4.42	29 - 125	48 - 148	1.19 - 5.61
Primary Clarifier						
Average* Removal (%)	32.0	38.2	-	35.1	38.9	-

* The removal efficiency seemed to improve under wet weather flow conditions.

TABLE 12 SECONDARY TREATMENT OPERATING CONDITIONS, EQUALIZED AND NON-EQUALIZED SYSTEMS. SPRING SAMPLING

	Flow (m^3/d)	MLSS (mg/L)	Sludge Settleability (%)	Aeration Tank Dissolved Oxygen (mg/L)	Oxygen Uptake Rate (mg/L•d)	Organic Loading (kg BOD/kg MLSS•d)
Equalized North System						
Average:	1401	2000	24	4.4	16.8	0.17
Range:	1075 - 1692	1550 - 2670	15 - 39	1.4 - 7.2	12.0 - 23.4	0.05 - 0.37
Non-Equalized South System						
Average:	1210	1750	24	4.7	13.9	0.16
Range:	895 - 1600	1440 - 2080	12 - 35	2.4 - 9.2	12.0 - 17.4	0.06 - 0.26

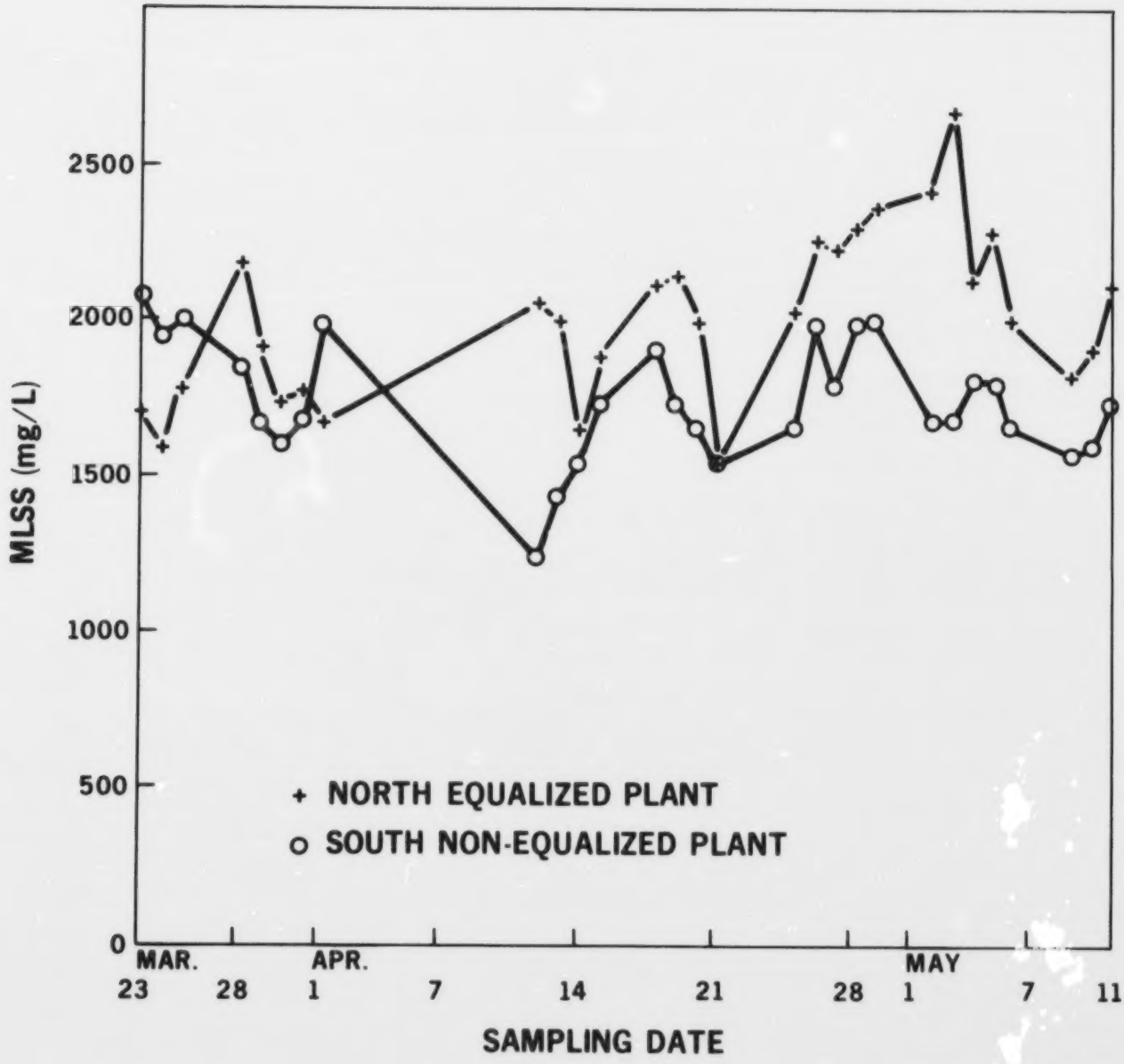

FIGURE 21 MLSS VARIATIONS, SPRING SAMPLING

Of principal concern during the spring monitoring program was the ability of the equalized plant to handle the increased hydraulic load without a deterioration in treatment performance. Secondary effluent sampling indicated that effluent quality in both systems deteriorated during the wet weather flow period as compared to dry weather flow conditions in the fall of 1976, notably in terms of effluent suspended solids. Hydraulic loadings of both systems increased substantially. Daily average flow to the equalized North System increased approximately 35 percent and was some 20 percent over the design capacity. Similarly, the hydraulic loading of the non-equalized South System increased about 20 percent, 10 percent over the design capacity.

An effort was made to maintain the aeration tank mixed liquor concentrations within the same range. Complete control of the Stouffville plant was difficult as operator surveillance was provided only eight hours per day, five days per week. It was found that control of the South System's solids concentration required much more frequent adjustments to sludge wastage rates.

The suspended solids and total BOD results are presented in the form of probability plots in Figures 22 and 23, respectively. The analytical results of the spring monitoring period are summarized in Table 13.

TABLE 13 SECONDARY EFFLUENT QUALITIES. SPRING SAMPLING

	Contaminant Concentration (mg/L)				
	BOD			Phosphorus (as P)	
	Total	Soluble	Suspended Solids	Total	Soluble
Equalized North System					
Average:	12	8	23	1.08	0.51
Range:	2 - 21	3 - 17	1 - 37	0.51 - 2.01	0.40 - 0.85
Non-equalized South System					
Average:	13	9	21	0.96	0.45
Range:	2 - 30	<5 - 17	5 - 42	0.33 - 2.27	0.07 - 1.95

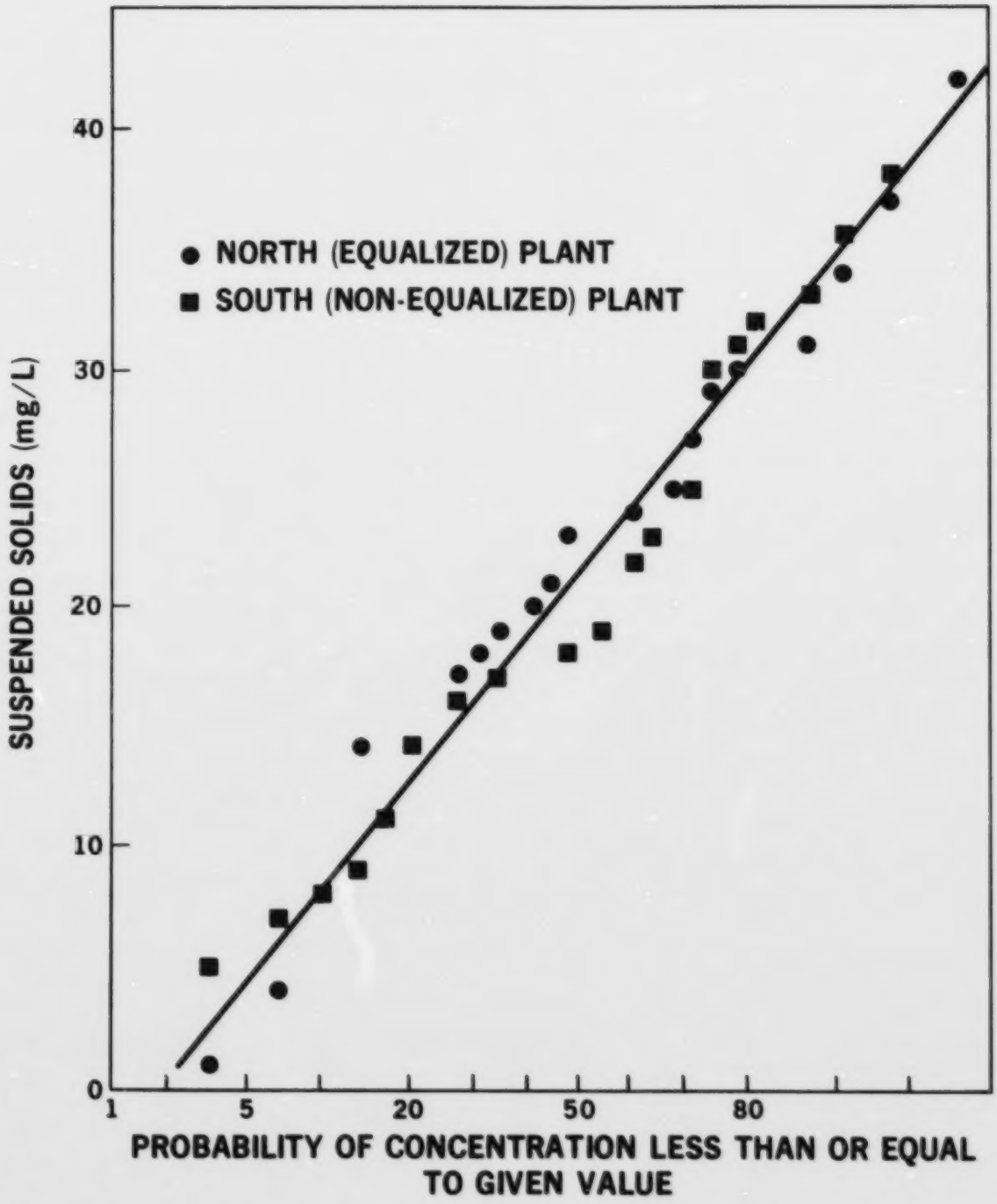

FIGURE 22 SECONDARY EFFLUENT QUALITY; SUSPENDED SOLIDS CONTENT. SPRING SAMPLING

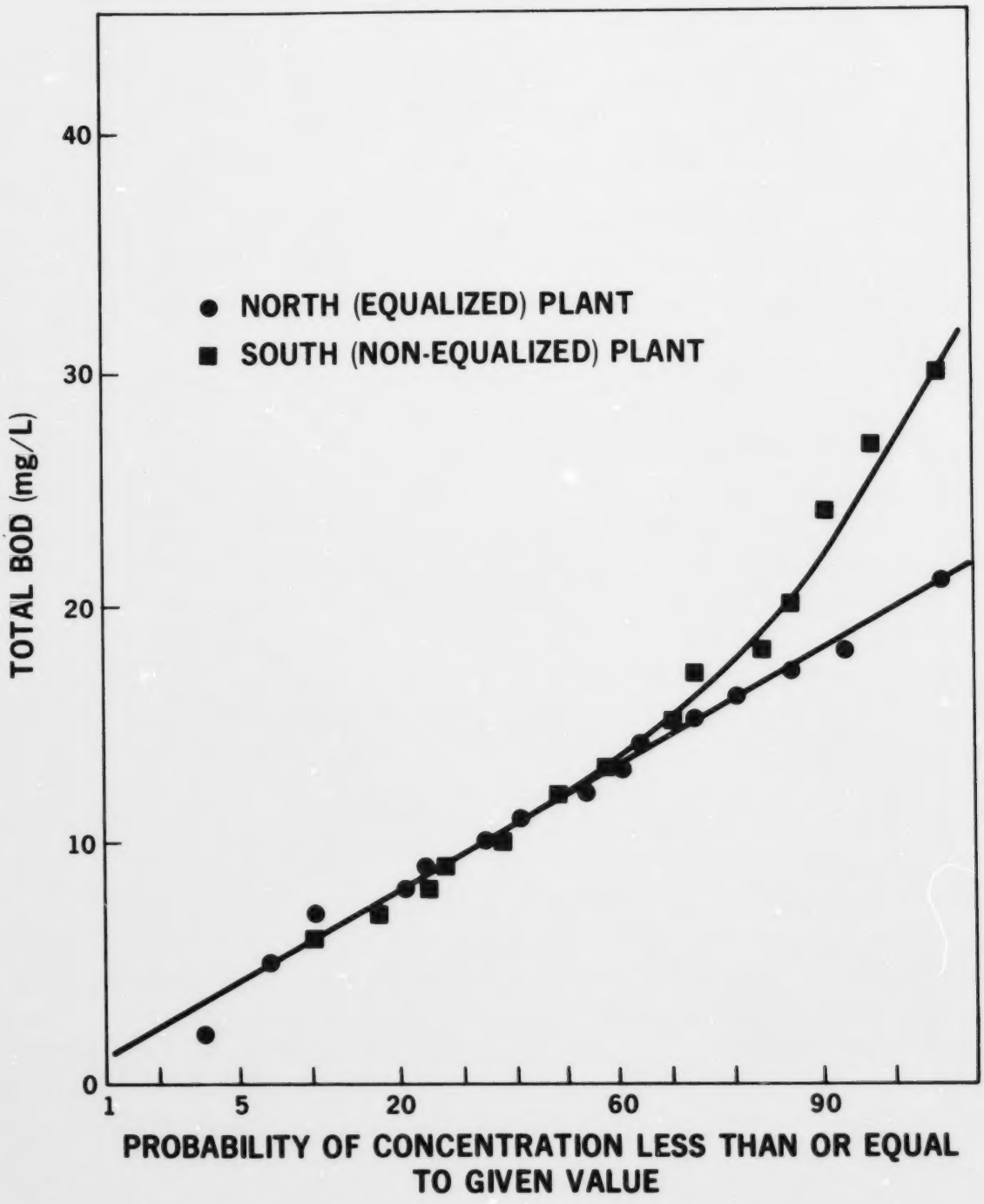

FIGURE 23 SECONDARY EFFLUENT QUALITY; BOD CONTENT. SPRING SAMPLING

There was no significant difference between the final effluent quality from the North and South Systems, despite the higher hydraulic loading of the equalized system. Some relatively higher BOD results were observed in the South System's effluent; however, this difference cannot be considered statistically significant at the 95 percent confidence level.

The lower mixed liquor concentrations in the South System resulted in approximately equivalent organic loadings in the aeration tanks. The loadings to both systems were relatively low (0.16 to 0.17 kg BOD/kg MLSS•d) and, as demonstrated by the low soluble BOD content of both effluents, the biological units were readily capable of handling the organic loads. Phosphorus removal efficiency was unaffected by the operating mode.

As the instantaneous feed rate to the North System varied over a wide range to compensate for varying inflow conditions, but remained constant and continuous for at least 24-hour periods, there was an opportunity to determine the effect of clarifier loading on suspended solids content of the effluent. The results are illustrated in Figure 24. Over a range of overflow rates from 24 to 44 $m^3/m^2 \cdot d$, there was no apparent correlation between effluent suspended solids concentration and clarifier hydraulic loading. The limiting hydraulic clarifier loading at Stouffville, beyond which effluent quality deteriorates, exceeds 44 $m^3/m^2 \cdot d$, the maximum continuous loading experienced during this study on the North System. It appears from these results that equalization can be effective if, in the particular application, the clarifier loading can be reduced to less than the limiting loading that results in excessive solids carryover. It also seems that the instantaneous flow is the controlling loading parameter.

Waste and return activated sludge concentrations were similar for both clarifiers despite the difference in hydraulic loading. The North System's waste activated sludge averaged 7100 mg/L suspended solids compared to 7150 mg/L in the South System. Average settled sludge volumes were identical after thirty minutes. However, from visual observations it was seen that the South System mixed liquor settled significantly more slowly than that in the North System, and this difference increased as the study progressed. The difference in sludge settleability was not, however, evident in the effluent suspended solids concentrations.

5.5 Comparison of Relative Sludge Production Rates

The average quantities of sludge pumped daily from the two primary clarifiers are summarized in Table 14. There was no significant difference between the sludge

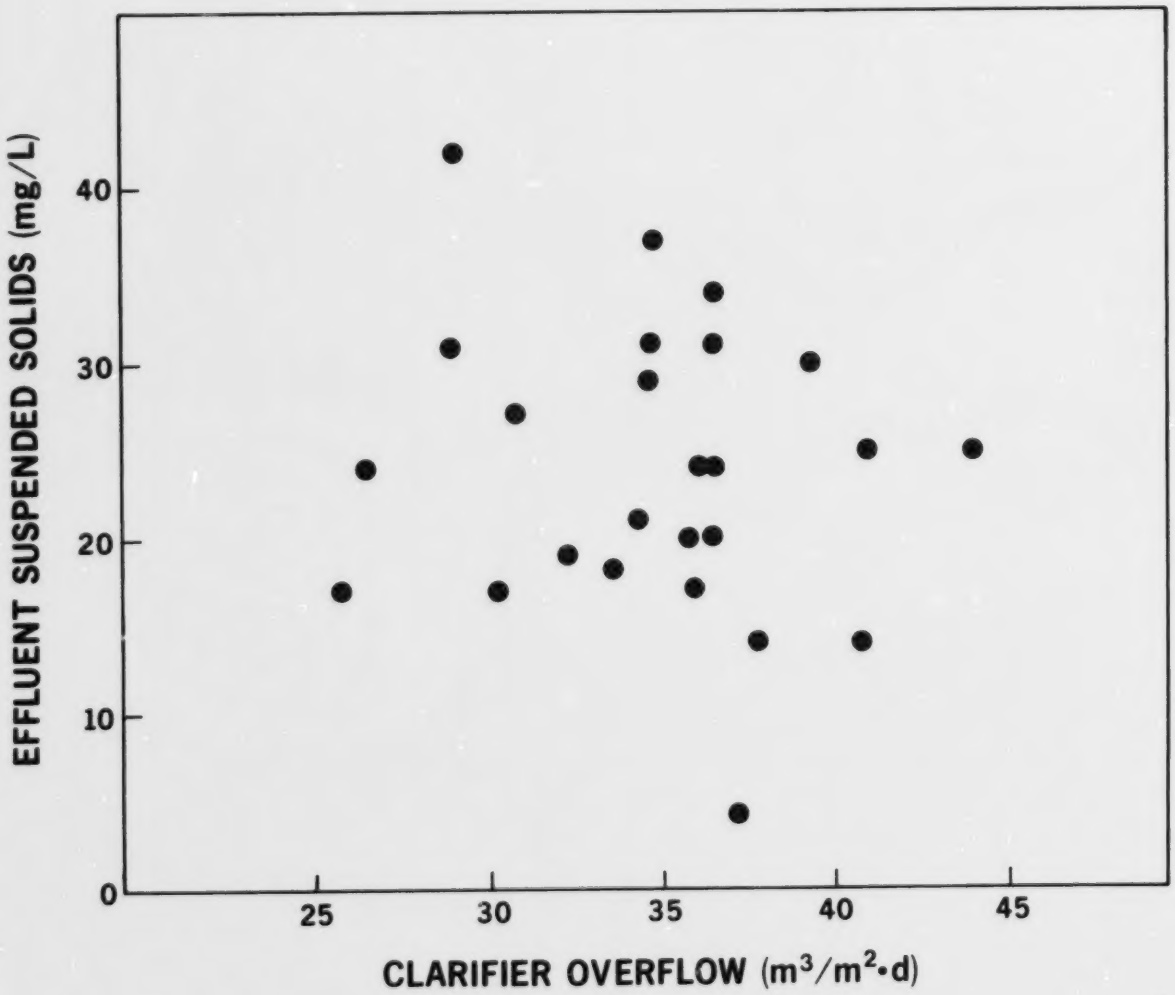

FIGURE 24 EFFECT OF CLARIFIER LOADING ON EFFLUENT QUALITY; EQUALIZED FLOW CONDITIONS. SPRING SAMPLING

TABLE 14 SLUDGE PUMPED DAILY FROM PRIMARY CLARIFIER. SPRING SAMPLING

Plant	Waste Sludge Volume (L/m^3)	Waste Sludge Concentration (% Solids)	Quantity of Waste Solids (g/m^3)
North System (Equalized)	11.6	2.36	275
South System (Non-equalized)	12.3	2.27	279

production rates under equalized and non-equalized flow conditions for the loadings experienced at the Stouffville plant during the spring 1977 sampling period. Sludge volumes wasted to the digester during the spring 1977 sampling were less than during the fall 1976 sampling as closer control of the pumping was maintained. Consequently, heavier sludge solids contents were attained in the waste sludge. On a weight basis per m^3 of raw sewage, more solids were removed from the treatment systems during the spring than during the fall.

5.6 Effect of Equalization on Treatment Plant By-pass Flow

The equalization tank at Stouffville is designed to operate as a primary clarifier with sludge scraping and scum removal capabilities. Flows in excess of the system's capacity can therefore be clarified prior to chlorination and discharge. This occurred on several occasions during the high flow period from April 1 to April 12, 1977. Samples of the overflow were obtained in order to assess the quality of the system's by-pass flow. Based on three samplings, average quality of the by-pass stream was 89 mg/L BOD and 57 mg/L suspended solids, representing a reduction in BOD of approximately 10 percent and in suspended solids of approximately 50 percent.

During a 10-day period of peak infiltration, approximately 5087 m^3 of sewage by-passed after clarification in the equalization tank. Total inflow to the plant during this period was 35 200 m^3, equivalent to 3520 m^3/d or 50 percent in excess of design hydraulic capacity. The equalization at Stouffville was not capable of handling this excessive flow. However, the impact of sewage by-pass was reduced by removal of the settleable solids and a portion of the BOD in the equalization basin. Loading on the receiving stream was reduced by about 45 kg of BOD and 318 kg of suspended solids during

this 10-day period due to the presence of the equalization tank. This reduction represents approximately 15 percent of the BOD and 100 percent of the suspended solids discharged in the secondary effluent during the same period.

6 COST IMPLICATIONS

6.1 Operating Costs

At the Stouffville Water Pollution Control Plant, flow equalization results in a net increase in operating costs. Raw sewage flows in excess of plant capacity are pumped for storage to the equalization tank by means of a level-controlled 19 kW pump. Sewage is returned by gravity at a variable rate to the wet well in response to a wet well level-actuated control valve. This system results in excessive pumping of sewage between the wet well and the equalization basin. Under these conditions, based on an average daily pumping time of about 21 hours and power charges of $0.02 kWh, power costs related to flow equalization are approximately $8.18 per day, equivalent to $74.49 per 1000 m^3 at average daily flow conditions. Comparable non-equalized flow conditions would result in power costs of $4.50 per day, equivalent to $40.65 per 1000 m^3 at average flow conditions.

The situation at Stouffville is not, however, respresentative of operational requirements for all equalization facilities. In Appendix I, a variety of possible pumping arrangements for in-line and side-line flow equalization are illustrated. These figures illustrate that operational costs depend on the actual set-up at each plant and are therefore strictly site-specific. It is considered impractical to draw any general conclusions with respect to the effects of flow equalization on pumping costs.

James F. McLaren Limited indicated in their report that significant capital savings may be realized in the areas of return sludge pumps and aeration equipment (6). By implication, similar savings should be possible in the area of operating cost. However, it is felt that a range of normal operating conditions for many treatment plants with respect to sludge return is from less than 20 percent to more than 100 percent of design flow without any apparent effect on the plant performance. Similarly, the range of dissolved oxygen on the aeration tank under normal operating conditions may range from 0.5 to over 6 mg/L. Under these circumstances and with existing data, it is impossible to evaluate the effect of equalization on these operating costs.

6.2 Capital Costs

The cost of the equalization tank at Stouffville was $88 820 in 1972. The treatment plant itself was constructed in three stages at the following costs:

Original plant	(1956)	$189 790
First extension	(1962)	$ 48 180
Second extension		
(including equalization tank, 1972)		$308 685

The costs shown above were obtained from Hisey and Barrington, Consulting Engineers, who designed and supervised all phases of constructions at the Whitchurch-Stouffville Water Pollution Control Plant.

When the costs of 1956 and 1962 constructions are expressed in 1972 dollars (using the Engineering News-Record construction index), the total cost of the plant is $900 000, of which equalization costs represent approximately 10 percent.

When assessing the economical implication of flow equalization at Stouffville, it became evident that this evaluation is applicable only to the set of circumstances at hand. The economic merits of flow equalization must therefore be determined on a site-specific basis as cost benefits are dependent on the situation at the treatment works involved. Further, flow equalization should be considered as one of the many available alternatives to be assessed in the design process.

Even though the circumstances under which equalization is economically feasible are site-specific, it is felt that there are several general factors that should be assessed as a part of the evaluation process. They are:

1) whether the situation under study involves an expansion of an existing facility or a new installation;
2) dry and wet weather flow variations, including instantaneous loadings, expected or experienced at the plant and the effects on plant operation;
3) the complexity of treatment processes involved;
4) the rate of occurrence of high-flow by-passes, their impact, and the economic implications of alternate methods of handling these by-passes; and
5) the possible capital savings involved in the design of treatment units under equalized flow conditions.

The evaluation of the feasibility of flow equalization will be simplified in the case of a new plant design. The possible savings resulting from flow equalization can be assessed with respect to possible reduction of treatment unit sizes, as well as in conjunction with overall pumping arrangements in the sewer system and in the plant. James F. McLaren Limited reported that substantial savings may be realized by reduction of return sludge pumping capacity and air supply equipment to cover the loading peak (6).

While it is realized that some saving can be achieved by reducing the aeration equipment as a result of flow equalization, it is questionable whether the return sludge pumping capacity within the accepted design range has a significant impact on plant performance.

It is clear that dry weather flow variation will be a very important factor in determining equalization feasibility. The methodology for determining equalization volume is described in the James F. McLaren report (6). The impact of peak flows resulting from short high-intensity precipitation on the operation of treatment plant and frequency of by-passes are also factors that must be assessed. A significant portion of these by-passes might be eliminated by the equalization tank, and some degree of treatment provided for flows beyond system capacity.

The degree of benefit resulting from flow equalization depends on the complexity of the treatment processes. Processes more complex than biological treatment or highly sensitive to hydraulic or organic loading will perform considerably more efficiently under equalized flow conditions.

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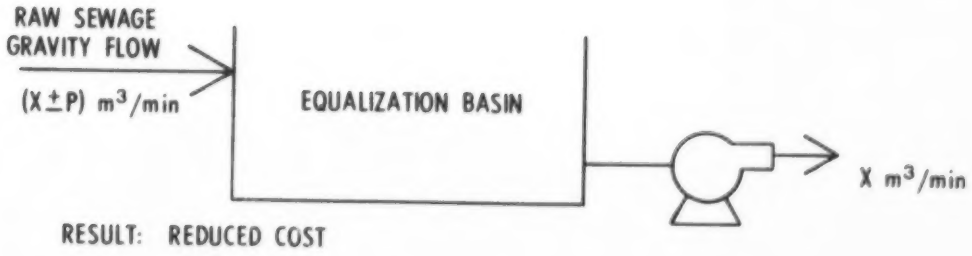
APPENDIX

ALTERNATIVE PUMPING ARRANGEMENT FOR EQUALIZATION FACILITIES

APPENDIX - ALTERNATIVE PUMPING ARRANGEMENT FOR EQUALIZATION FACILITIES

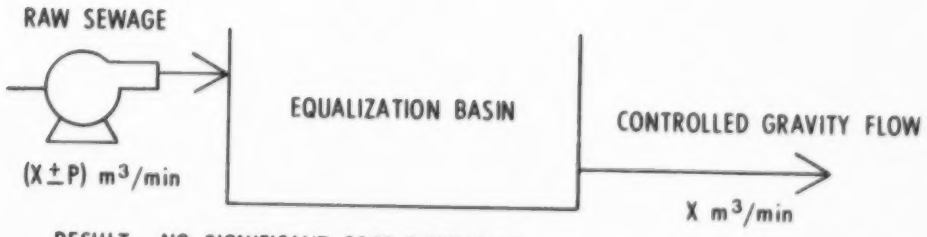
1. In-Line Flow Equalization

A.



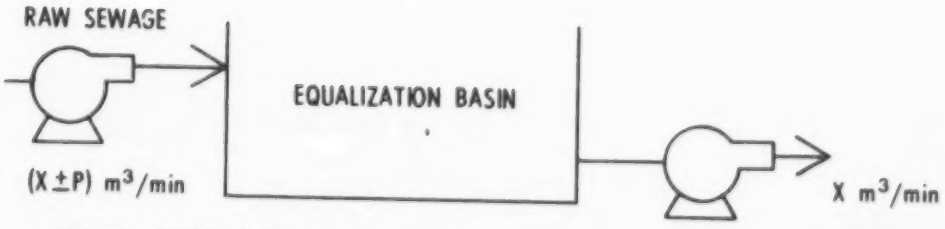
RESULT: REDUCED COST

B.



RESULT: NO SIGNIFICANT COST DIFFERENCE.

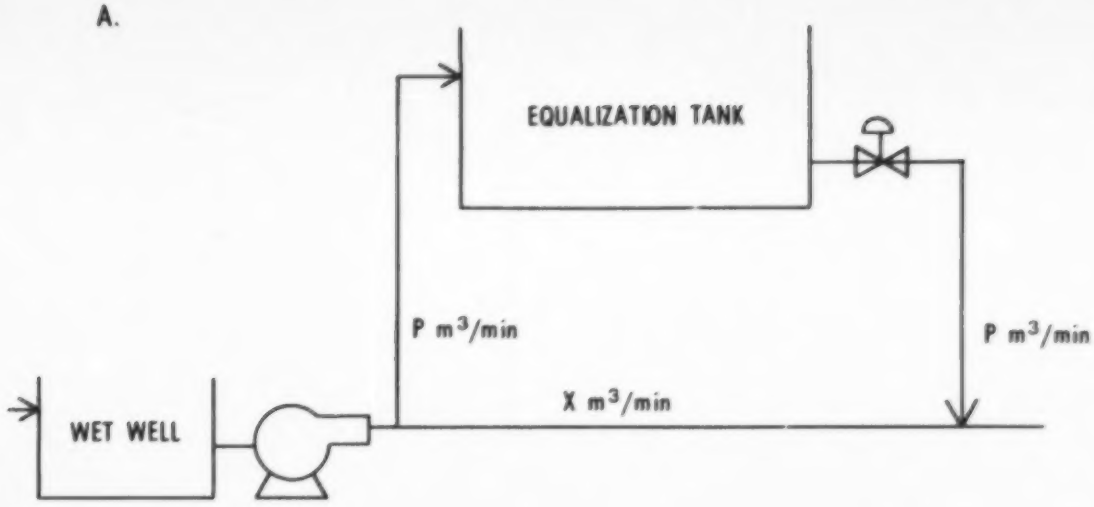
C.



RESULT: EXTRA COST

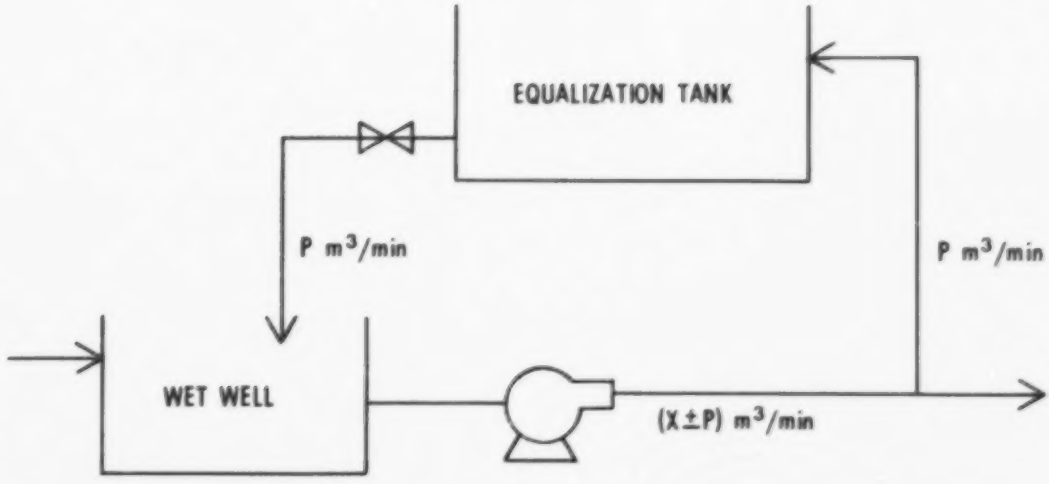
2. Side-Line Flow Equalization

A.



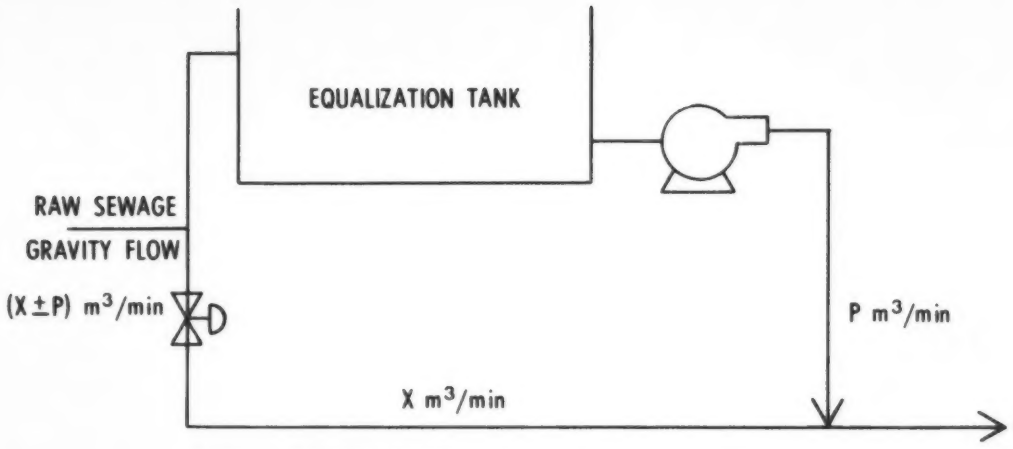
RESULT: NO SIGNIFICANT COST DIFFERENCE.

B.



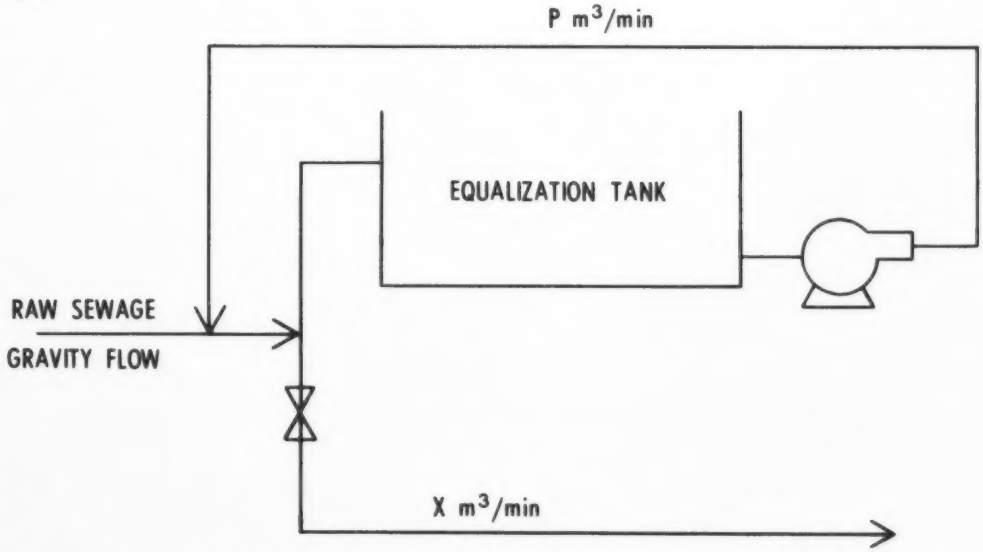
RESULT: EXTRA COST IF PEAK FLOW IS CIRCULATED BETWEEN WET WELL AND EQUALIZATION TANK.

C.



RESULT: REDUCED COST

D.



RESULT: INCREMENTAL COST DEPENDS ON NUMBER OF RECIRCULATIONS BETWEEN EQUALIZATION TANK AND INFLUENT WORKS.